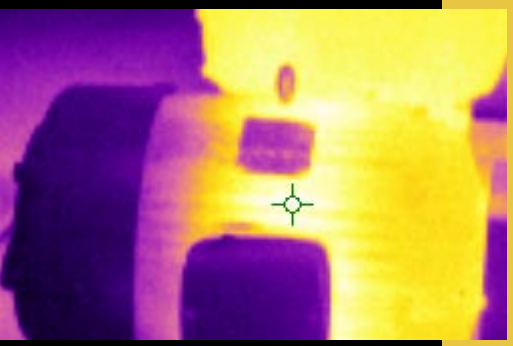
Tequipment.NET
205 Westwood Ave
Long Branch, NJ 07740
1-877-742-TEST (8378)
Fax: (732) 222-7088
salesteam@Tequipment.NET

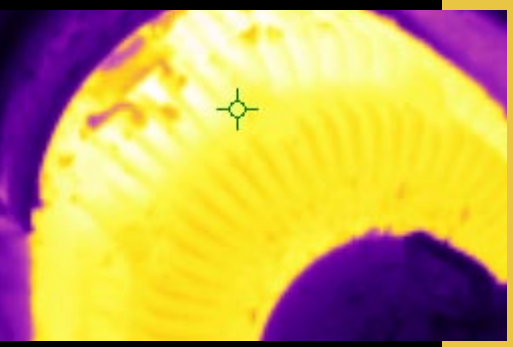
FLUKE®

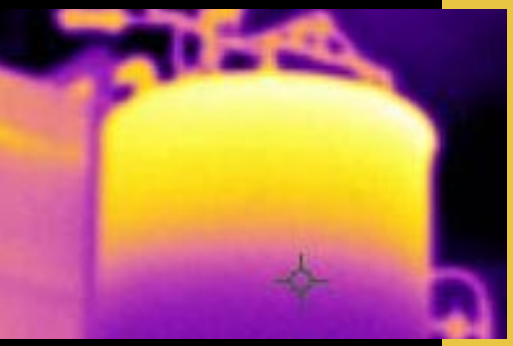
Thermography

Education Series

A comprehensive collection of applicaction notes and data sheets focusing on Thermography solutions from Fluke.







Click on the document title below to open the document.

- Three new infrared instruments from Fluke
- Detecting electrical unbalance and overloads
- Developing an Inspection Program
- Electrical, insulation and thermal measurements for motors and drives
- Implementing an infrared thermography maintenance program
- Infrared inspecting for building and facilities maintenance
- Inspecting bearings
- Inspecting electric motors
- Inspecting steam systems
- Loose or corroded electrical connections
- Maintenance routing
- Moisture in building envelopes
- Qualitative vs. quantitative inspections
- Thermography and PdM: How to maximize your ROI
- Tests and measurements for electrical fire prevention
- The basics of predictive / preventive maintenance
- Thermal predictive maintenance at a coal plant
- Thermography and motor condition monitoring at a paper mill
- Ti30 product brochure
- Creating successful reports
- Monitoring transformers
- Industrial gearboxes
- Thermal process monitoring
- Tanks and vessels
- Inspecting furnaces and boilers
- How one plant brought thermography in-house

For additional information go to: http://www.fluke.com

FLUKE®

Three new infrared instruments from Fluke

Application Note

With night vision equipment being used in Iraq and shown regularly on the evening news, nearly everyone is aware of what makes this life-saving technology possible: infrared (IR) emissions from warm bodies and equipment. That's the same kind of energy that makes equipment-saving strategies possible wherever sound maintenance procedures are required.

There are two useful IR technologies available for maintenance: IR thermometry and thermal imaging, also known as IR thermography. The former measures the average temperature of an area on an object's surface. The latter uses infrared emissions to make a two-dimensional, *quantitative* image of the temperatures at points on an object's surface. By contrast, the night vision equipment used by US troops in Iraq provides *qualitative* images that allow the viewer only to identify objects and features.

IR thermometers and thermal imagers are essential tools in any comprehensive predictive maintenance (PdM) program. They prevent failures by identifying conditions that indicate impending failure and providing data that helps technicians determine whether remedial action is warranted. If it is, maintenance personnel can repair the equipment before it fails and during a scheduled shutdown. The benefits: no unplanned downtime and maximized uptime using less labor and fewer replacement parts. Only equipment that needs repairing gets repaired.

Since increases in temperature are associated with nearly all mechanical and electrical failures, thermal imaging and IR thermometry have broad application in PdM programs. Three new products from Fluke take advantage of that fact.

The Fluke Ti30™ Thermal Imager

Until recently thermography was so complex and expensive that only certified specialists used the technology. Now, the Fluke Ti30 Thermal Imager is changing all of that.

The Ti30 is an affordable, compact, handheld, ergonomically designed device. It literally puts thermal imaging into the hands of the people most familiar with a facility and its equipment: in-house maintenance technicians and equipment operators.

The technology behind the Ti30 is as powerful as the instruments used by specialists, but it makes thermal imaging a point-and-shoot process. It has ample on-board computer power to collect data for a PdM program, and it interfaces with software on a host computer or network, so that maintenance managers can track temperature measurements and compare thermal images over time.

Since consistency is key to effective periodic PdM inspections, the Ti30 system software allows the supervisor to build and edit a route on the PC and then upload it into the imager. The imager's user interface then describes the location of each stop and the images needed, leading the technician through the route. This ensures that the correct equipment gets inspected and the correct images recorded.

The Ti30 has a sighting window that displays the thermal image along with readouts of status and mode. At a route stop, the technician simply uses the sighting window to frame the required thermal images, clicks the trigger and presses the save button (up arrow) for each one. Also available to the tech are features for managing the temperature level and span, switching the display from color to black and white and turning on a built-in sighting laser.

Finally, the Fluke Ti30 thermal imager comes standard with powerful InsideIR™ PC software for data analysis and report writing, for a complete thermal PdM program. Included with purchase and with no licensing restrictions and free periodic upgrades available via the web, the software is the most affordable on the market today. Also included is two days of professional thermography training*. By focusing on applications and infrared technology basics, this program ensures a fast return on investment.

*Two-day training package available in North America only. Other training programs vary by region.

The 570 Series IR Thermometer

Infrared thermometers in the Fluke 570 Series — the 572, 574 and 576 — are among the most advanced available. They all feature accuracies of ± 0.75 % of reading and high resolution represented by distance-to-spot ratios of 60:1. This ratio means, for example, that at a distance of 60 inches from an object these thermometers will measure the temperature of a spot about one inch in diameter. In other words, they can measure the temperature of small objects at a relatively long distance and very small objects close up. In fact, the Fluke 572, 574 and 576 models are available with a close focus option featuring a 50:1 distance to spot ratio and a minimum measurement spot to be as small as 6 mm (.24 in).

Many models of IR thermometers have a laser beam for sighting a target, but a single beam in the middle of a spot only tells the user where the center of the spot is. All Fluke 570 Series units have a three-dot sighting system that reveals not only where the center of the spot is but also where its edge is. The Fluke 570 Series laser sighting also features a special laser that appears twice as bright to the human eye (while maintaining the same safety rating as less bright lasers). This feature makes accurate sighting easier in a variety of lighting conditions and at varying distances.

All thermometers in the Fluke 570 Series record temperatures from -30 °C to +900 °C (-25 °F to +1600 °F), a sizable range. Such a wide temperature range extends the applications for 570 Series thermometers. It means that maintenance personnel and even production personnel can measure the temperatures of equipment or products-in-process that are very cold or very hot and everything in-between.

Non-contact thermometers use the amount of energy emitted by an object and the efficiency with which the object's material emits infrared energy (its "emissivity") to calculate the object's surface temperature. While some instruments have their emissivity preset close to the emissivity of most organic materials and painted or oxidized surfaces, all the thermometers in the Fluke 570 Series allow their emissivity settings to be adjusted to match the surface characteristics of specific targets. The 574 and 576 models also have easily accessible preset emissivity settings for common materials. Using this feature saves the user time in not having to look up the proper emissivity setting before taking a

reading. Of course, when a thermometer's emissivity setting matches the emissivity of the target, the reading is more accurate.

All thermometers in the Fluke 570 Series have a very fast 250 mSec response time. This high speed means that one of these thermometers can record accurate readings even in situations where target temperatures are changing rapidly. It also means that serious problems can be diagnosed immediately with no need to shut down equipment to take a reading.

Other features of the Fluke 570 Series include backlit liquid crystal displays for viewing in poorly lit areas and the capability to store the last 10 readings and then display them as a bar graph for easy comparison. Each also has a high alarm warning that is both audible and visible.

A Fluke 572 thermometer has all of the aforementioned capabilities. Moving up to the Fluke 574 and 576 add the power of 100-point data logging. This feature, along with software for logging, graphing and analyzing temperature data on a PC and an RS-232 (574) or USB (576) connection to move the data from the thermometer to the PC, minimizes the time once used to transcribe data and streamlines analysis. Reports get written faster and more accurately, and needed repairs are more likely to happen before equipment fails.

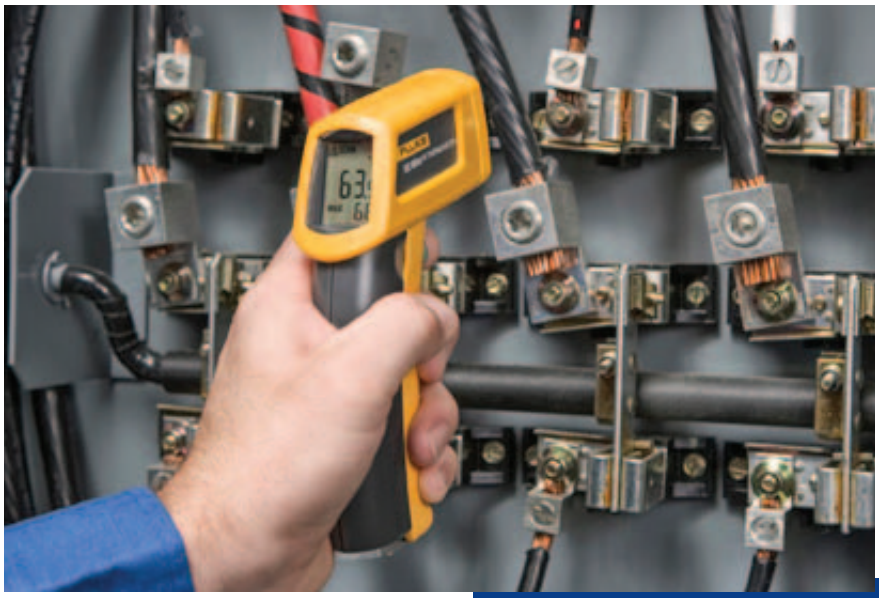
Along with their inherent data logging capability, the 574 and 576 models have customizable features such as log names, high and low alarms, emissivity values for special conditions, etc. A technician can customize an instrument to conform to his or her inspection route. In addition, a version of the 574 has been tested by Factory Mutual, a US organization, and has received a nonincendive (Class I, Division 2) approval. The nonincendive model is not available with the close-focus option.

To all of this, the Fluke 576 adds digital photography. When a temperature reading is recorded, the instrument records the temperature on the photo of the target along with the date and time of the measurement. Having a photographic record of measurements is a powerful documentation and reporting tool.

At the end of an inspection route, a technician using a Fluke 574 or 576 IR Thermometer uploads the collected data and, if using the 576 model, images. At this point, she or he has several options. The data can be compared to data recorded earlier. Questions can be asked and answered: Was the inspection done properly? Was this measurement consistent with earlier ones in terms of location and temperature recorded? Is any equipment's temperature trending upward or downward?

The technician can record the equipment data in tabular view; tailor high or low alarms to specific locations; view minimum, maximum and average temperatures for specific locations; graph the data to reveal trends and much more. If warranted, a report on the status of any piece of equipment can be created. Then, the report may be distributed electronically or printed for physical distribution or even posted on a company's intranet.

If the technician had used the Fluke 576, photos for added impact or to help guide repair personnel to a location could accompany any of the documentation and reporting just mentioned.



The Fluke 62 Mini IR Thermometer

For technicians just getting started with IR thermometry, there is the Fluke 62 Mini IR thermometer. Like other IR thermometers, it serves to measure increases in temperature that often indicate potential problems with mechanical equipment, electrical circuits and building systems.

The Fluke 62 Mini is faster, more accurate, and measures a greater range of temperatures than earlier generations of so-called "mini" IR thermometers. It has single-point laser sighting and can capture, along with the current reading, the maximum reading among a range of readings. It measures temperatures from -30 °C to +500 °C (-20 °F to +932 °F), making applications for it quite extensive. In addition, it is accurate to ± 1 % of reading.

The 62 Mini has a fixed, preset emissivity of 0.95, which is the emissivity value for most organic materials as well as painted or oxidized surfaces. So, it can't accurately measure the temperature of objects with shiny surfaces unless steps are taken to eliminate the reflected energy. Typical moves are to compensate by covering the surface with masking tape or flat black paint.

Of course, it is necessary to allow enough time for the tape or paint to reach the temperature of the material underneath.

The distance-to-spot ratio of Fluke 62 Mini Thermometer is 10:1, making it best for applications where users can safely stand close to targets. However, despite this relatively low resolution (compared to the 570 Series) and its fixed emissivity settings, it can be quite useful to homeowners, auto mechanics and heating, ventilation and air-conditioning technicians, working fairly close-up and not needing the extraordinary temperature range of the 570 Series.

New Fluke infrared tools and applications

	62 Mini Infrared Thermometer	57X Series Infrared Thermometer	Ti30 Thermal Imager
Recommended Uses	Basic electrical, light industrial maintenance checks	Predictive and preventive maintenance, electrical, process monitoring, heavy equipment, quality assurance programs	All types of maintenance that require a fast overview of existing temperature distribution
Temperature Range	-18 to 275 °C	-30 V to 900 °C (Standard) -50 to 500 °C (SubZero option)	-10 to 250 °C
Typical Distance to Target (spot)	Up to 1 m	Up to 10.5 m	Between 60 cm and 15 m
Optical Resolution (D:S)	8:1	60:1 (Standard focus) 50:1 (Close focus)	90:1 for temperature measurement
Accuracy	+/- 2 %	+/- .75 %	+/- 2 %
Sighting	Laser point	High precision coaxial laser sighting	Single-point laser
Emissivity	Pre-set to 0.95	Adjustable	Adjustable
Data Logging	N/A	574, 576: 100 data points	Up to 100 images with temperature data
Data Output	N/A	574: RS-232 or 1 mV per degree 576: USB 1:1	USB 1:1

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 4/2005 2446724 A-US-N Rev A

FLUKE®

Detecting electrical unbalance and overloads

Application Note

Thermal images are an easy way to identify apparent temperature differences in industrial three-phase electrical circuits, compared to their normal operating conditions. By inspecting the thermal gradients of all three phases side-by-side, technicians can quickly spot performance anomalies on individual legs due to unbalance or overloading.

Electrical unbalance can be caused by several different sources: a power delivery problem, low voltage on one leg, or an insulation resistance breakdown inside the motor windings.

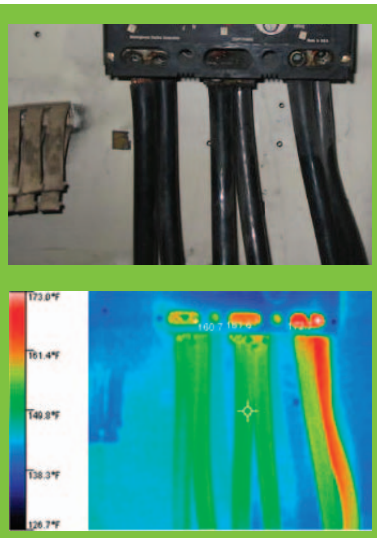
Even a small voltage unbalance can cause connections to deteriorate, reducing the amount of voltage supplied, while motors and other loads will draw excessive current, deliver lower torque (with associated mechanical stress), and fail sooner. A severe unbalance can blow a fuse, reducing operations down to a single phase. Meanwhile, the unbalanced current will return on the neutral, causing the utility to fine the facility for peak power usage.

In practice, it is virtually impossible to perfectly balance the voltages across three phases. The National Electrical Manufacturers Association (NEMA) defines unbalance as a percentage: % unbalance = [(100)(maximum deviation from average voltage)] ÷ average voltage. To help equipment operators determine acceptable levels of unbalance, the NEMA has drafted specifications for multiple devices. These baselines are a useful point of comparison during maintenance and troubleshooting.

What to check?

Capture thermal images of all electrical panels and other high-load connection points such drives, disconnects, controls and so on. Where you discover higher temperatures, follow that circuit and examine associated branches and loads.

Check panels and other connections with the covers off. Ideally, you should check electrical devices when they are fully warmed up and at steady state conditions with at least 40 % of the typical load. That way, measurements can be properly evaluated and compared to normal operating conditions.



The connections on this evaporator pump read over 50 degrees hotter on phase C.

Caution:

Only authorized and qualified personnel using the appropriate personal protective equipment (PPE) should remove electrical panel covers.

FLUKE®

What to look for?

Equal load should equate to equal temperatures. In an unbalanced load situation, the more heavily loaded phase(s) will appear warmer than the others, due to the heat generated by resistance. However, an unbalanced load, an overload, a bad connection, and a harmonic imbalance can all create a similar pattern. Measuring the electrical load is required to diagnose the problem.

Note: A cooler-than-normal circuit or leg might signal a failed component.

It is sound procedure to create a regular inspection route that includes all key electrical connections. Using the software that comes with the thermal imager, save each image you capture on a computer and track your measurements over time. That way, you'll have baseline images to compare to later images. This procedure will help you determine whether a hot or cool spot is unusual. Following corrective action, new images will help you determine if repairs were successful.

What represents a "red alert?"

Repairs should be prioritized by safety first—i.e., equipment conditions that pose a safety risk—followed by criticality of the equipment and the extent of the temperature rise.

NETA (InterNational Electrical Testing Association) guidelines dictate immediate action when the difference in temperature (ΔT) between similar electrical components under similar loading exceeds 15 °C (27 °F) or when the ΔT between an electrical component and the ambient air temperatures exceeds 40 °C (72 °F).

NEMA standards (NEMA MG1-12.45) warn against operating any motor at a voltage unbalance exceeding one percent. In fact, NEMA recommends that motors be de-rated if operating at a higher unbalance. Safe unbalance percentages vary for other equipment.

What's the potential cost of failure?

Motor failure is a common result of voltage unbalance. Total cost combines the cost of a motor, the labor required to change out a motor, the cost of product discarded due to uneven production, line operation and the revenue lost during the time a line is down.

Assume the cost to replace a 50 hp motor each year is $5000 including labor. Assume 4 hours of downtime per year with income loss of $6000 per hour. ***Total Cost: $5000 + (4 x $6000) = $29,000 annually***

Follow-up actions

When a thermal image shows an entire conductor is warmer than other components throughout part of a circuit, the conductor could be undersized or overloaded. Check the conductor rating and the actual load to determine which is the case.

Use a multimeter with a clamp, a clamp meter or a power quality analyzer to check current balance and loading on each phase. On the voltage side, check the protection and switchgear for voltage drops. In general, line voltage should be within 10 % of the nameplate rating. Neutral to ground voltage tells you how heavily your system is loaded and helps you track harmonic current. Neutral to ground voltage higher than 3 % should trigger further investigation.

Loads do change, and a phase can suddenly be 5 percent lower on one leg, if a significantly large single-phase load comes online. Voltage drops across the fuses and switches can also show up as unbalance at the motor and excess heat at the root trouble spot. Before you assume the cause has been found, double check with both the thermal imager and multimeter or clamp meter current measurements.

Neither feeder nor branch circuits should be loaded to the maximum allowable limit. Circuit load equations should also allow for harmonics. The most common solution to overloading is to redistribute loads among the circuits, or to manage when loads come on during the process.

Using the associated software, each suspected problem uncovered with a thermal imager can be documented in a report that includes a thermal image and a digital image of the equipment. That's the best way to communicate problems and to suggest repairs.

Fluke. *Keeping your world up and running.*

Imaging Tip

The primary use of thermography is locating electrical and mechanical anomalies. Despite a popular perception to the contrary, a device's temperature—even its relative temperature—may not always be the best indicator of how close it is to failure. Many other factors should be considered, including changes in ambient temperatures and mechanical or electrical loads, visual indications, the criticality of components, histories of similar components, indications from other tests, etc. What all of this indicates is that thermography serves best as part of a comprehensive condition monitoring and predictive maintenance program.

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2518873 A-EN-N Rev A

Developing an Inspection Program

There are no easy solutions to the high costs of maintenance. The amount of time and effort required to select predictive methods that will provide the most cost-effective means to evaluate the operating condition of critical plant systems; establish a program plan; create a viable database; and establish a baseline value is substantial. The actual time and manpower required will vary depending on plant size and the complexity of process systems. For a small company, the time required to develop a viable program will be about three man-months. For large, integrated process plants, this initial effort may be as much as 15 man-years. Are the benefits worth this level of effort? In almost every instance, the answer is an absolute yes.

Here are 10 steps that can help you implement a successful total plant predictive maintenance program:

1. Determine Existing Maintenance Costs

   The most difficult step in the initial justification of a predictive maintenance program is the determination of actual maintenance costs. Most plants do not track all controllable costs that are directly driven by the maintenance operation. In most cases, the cost-accounting function limits cost tracking to actual labor and material used to maintain plant equipment. They do not include the impact of maintenance on availability, production capacity, operating costs, product quality and the myriad of other factors that limit plant effectiveness.

   In addition to maintenance labor and material costs, your evaluation should include all maintenance-related costs associated with delays, reduced capacity operation, overtime premiums, and product quality. Safety and environmental compliance should be included in your evaluation.

   In some cases, your accounting department can help develop a close approximation of the true costs of maintenance. Explain the reason for your request and let them help quantify the historical plant costs.

   The cost history developed at this time is extremely important. Initially it will be used to develop a cost-benefit analysis and justification for your predictive maintenance program. Later, this data set will become the baseline for quantifying the actual benefits derived from the program. Plants should not shortcut this part of the program implementation. Accuracy and completeness of this data set is critical to the long-term success of your program. The majority of programs that failed in the first two years following implementation can be directly attributed to the lack of quantified results.

2. Select Predictive Systems and Vendors

Another major contributor to program mortality is the selection of either the wrong predictive technologies or a vendor who cannot provide long-term program support. Extreme care must be used during this selection process.

A total plant predictive maintenance program must use a combination of monitoring and diagnostic techniques to achieve maximum benefits. None of the individual technologies, such as thermal imaging and vibration, provide all of capabilities that are required to evaluate critical plant process and systems. What combination of technologies is best for your plant?

Unfortunately, there is no easy answer to this question. The predictive requirements of each plant are different. As a minimum, your program should include (1) key operations processes analysis, (2) thermal imaging, (3) process parameters, and (4) visual inspection. Lubricating oil and wear particle analysis (tribology) should be used only where the added information derived will justify the costs.

Care should be exercised when selecting predictive systems and vendors. As a minimum, the following should be considered when selecting predictive maintenance systems:

a. Adequacy to Your Specific Needs

None of the predictive maintenance systems are perfect. Each has its unique strengths and weaknesses. For example, many of the vibration monitoring systems cannot handle machine speeds below 600 RPM or lack the ability to use a variety of transducers. Either or both of these limitations will reduce the benefits that can be derived from your program. Define the specific requirements for your systems and make sure that the selected systems will fulfill all requirements.

b. Stability of System and Vendor

Predictive maintenance programs are intended to be life of plant, continuous improvement programs. Therefore, it is essential that the systems you select for your plant will remain viable for an extended time period. Competition within the predictive maintenance arena is fierce and many of the early players have gone out of business, merged with other companies or constantly change their system structure. All of these factors will affect the long-term status of your program. Your evaluation should include:

- Financial strength of the vendor;
- History of product development;
- Technical support, and
- Existing client base.

3. Training Requirements and Support

Most predictive maintenance vendors will offer some level of training. However, most of these training programs are directed toward the use of a specific system, i.e. software and instrumentation, rather than comprehensive use of the technology.

As a reference, I have used all of the predictive maintenance technologies for more than 30 years and still learn something new every day. There are a number of vendors that offer technical training that can support your predictive maintenance program. However, you should carefully evaluate the merit of their courses before electing to use them as training support. In general, independent training companies, with no association with equipment manufacturers, can provide high quality training with an unbiased approach.

4. Get Management Support

   Lack of a total commitment from plant or corporate management to provide the resources required to implement and maintain a program is the single largest reason for failure of predictive maintenance programs. There are a number of reasons for lack of long-term commitment. However, in most cases, it stems from the lack of planning and justification in the pre-program effort. Management must know the true cost and potential benefits of the program before it begins. After implementation, they must be continually informed of the progress and actual benefits that the program provides. Therefore, it is imperative that a viable means of quantifying the actual results of the program be developed and the ongoing status of the program communicated to all key management staff.

   Management support should include implementation of a formal maintenance planning function, a viable information management program and craftsman skill training in order to gain maximum benefits from predictive maintenance. The predictive program will provide the trigger for maintenance activities, but without proper planning and repair skills, full benefits cannot be obtained. The information management program has two functions: (1) maintain equipment histories and (2) track program benefits.

5. Develop A Program Plan

   A definite program plan that includes all activities required by a total plant predictive maintenance program must be developed before implementing your program. The program plan should include:

   - Specific scope of program;
   - Goals and objectives; and
   - Methods that will be used to implement, maintain and evaluate the program.

   The plan should also include specific return-on-investment (ROI) milestones that can be used to measure the success of the program.

6. Dedicated Personnel

   A key part of a successful program is a full-time, dedicated staff. The program cannot be implemented or maintained with part-time personnel. Regardless of the predictive maintenance techniques used for the program, regular, periodic

monitoring of critical plant parameters is an absolute necessity. Most programs implemented with part-time staff have failed because activities required to maintain the program have been delayed or ignored because of other pressing demands on staff time.

7. Establish Accountability

   The predictive maintenance team must understand the reason for implementing the program and be accountable for its success or failure. Staff commitment is an absolute requirement for a successful program. Without this total commitment, the program will probably fail.

   Division or area managers must also accept responsibility for program success. In most plants, these managers control the resources, both financial and personnel, within their departments. Without their full support and commitment to the program, little can be accomplished.

8. Develop A Viable Database

   The actual benefits derived from a program will depend on the accuracy and completeness of the database developed for the program. All predictive maintenance technologies depend on a clear, detailed definition of the critical equipment that is included in the program.

   Database development requires a tremendous effort in both manpower and time. A typical microprocessor-based predictive maintenance program may require as much as 10 man-years to develop in a large, integrated process plant. Even small plants must invest an average of 1-3 man-years in this startup effort. However, the time is well spent. The initial investment will greatly reduce the manpower and time required to maintain your program and will greatly improve the benefits derived from the program.

   Many program failures result from shortcutting the database development step. In part, this is driven by the absence of accurate machine data and by the restrictions of many predictive maintenance systems. To achieve maximum benefits from your program, invest the time and manpower required to establish a complete database.

9. Maintain the Program

   Do not quit after the implementation phase is complete. Many programs fail because the plant staff did not follow through after the development stage. Follow the program plan. Meet each of the schedules and milestones developed in the program plan. Constantly evaluate the program's progress and correct any errors or problems that may exist. A successful predictive maintenance program must be dynamic. Follow through.

10. Communicate

    Communication is absolutely necessary for long-term success. All successful programs have a well-defined communications plan that includes transmittal of corrective actions identified by the program; feedback from manufacturing; and a regular program status report that is circulated throughout the plant and corporate management team.

    Program justification is a never-ending process. Management and other plant team members must be continually informed of the program's status and the benefits derived from it. Failure to communicate will severely reduce the potential for a successful program.

The Payoff

Although the effort required to implement and to maintain a total plant predictive maintenance program is great, so are the benefits that can be derived. Properly implemented and maintained, predictive maintenance, as part of a total plant performance management program, can reduce the negative impact of maintenance on availability, product quality, and operating profit.

Predictive maintenance can transform the maintenance operation from an expensive support function to a full member of the profit generating team in your plant. Do not expect an easy quick fix. Like all things of value, a certain amount of effort is required to gain positive results. If you follow these steps, you can establish a total plant predictive maintenance program that will provide maximum benefits for your plant.

FLUKE®

Electrical, insulation and thermal measurements for motors and drives

Insulation multimeters and thermal imagers: Two testers that go great together.

Application Note

Most facilities need to get maximum life out of their motors, because they are expensive to replace in terms of both money and labor. Electrical, insulation resistance and thermal measurement are three tests that can troubleshoot motors, drives, and associated electrical panels and prolong their operational lifetime. Used together, thermal imagers can detect potential problems and insulation resistance and electrical tests can determine the cause.

Handheld thermal imagers such as the Fluke Ti30 can collect heat signatures from a range of motors, from 1000 hp down to 5. A thermal imager is good for spot checks, to see if motors and associated panels and controls are operating too hot, and for troubleshooting, to track down the specific failed component at fault. It can also check for phase imbalance, bad connections, and abnormal heating on the electrical supply.

An insulation multimeter like the Fluke 1587 can perform most of the other tests you need to troubleshoot and maintain motors. When a motor is having problems, check the supply voltage and then use insulation testing to check the starter and control contacts, measure the insulation resistance of the line and load circuits to ground, and winding resistance phase to phase and phase to ground.

About thermal measurements

A motor's heat signature will tell you a lot about its quality and condition. If a motor is overheating, the windings will rapidly deteriorate. In fact, every increase of 10°C on a motor's windings above its design operating temperature cuts the life of its windings' insulation by 50 percent, even if the overheating is only temporary.

If a temperature reading in the middle of a motor housing comes up abnormally high, take a thermal image of the motor and find out more precisely where the high temperature is coming from, i.e. windings, bearings or coupling. (If a coupling is running warm it is an indicator of misalignment.)

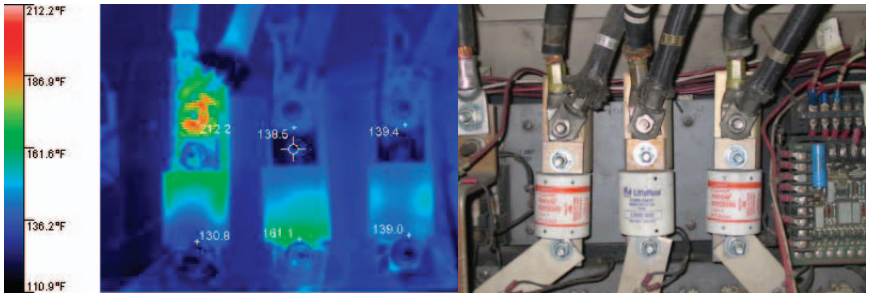
There are three primary causes for abnormal thermal patterns; typically most are the result of a high-resistance contact surface, either a connection or a switch contact. These will usually appear warmest at the spot of high-resistance, cooling off the further away from the spot. This thermal image shows a classic pattern in the center phase connection on the line-side of a breaker; note how the conductor cools off at the top of the image.

Load imbalances, whether normal or out of specification, appear equally warm throughout the phase or part of the circuit that is undersized/overloaded. Harmonic imbalances create a similar pattern. If the entire conductor is warm, it could be undersized or overloaded; check the rating and the actual load to determine which.

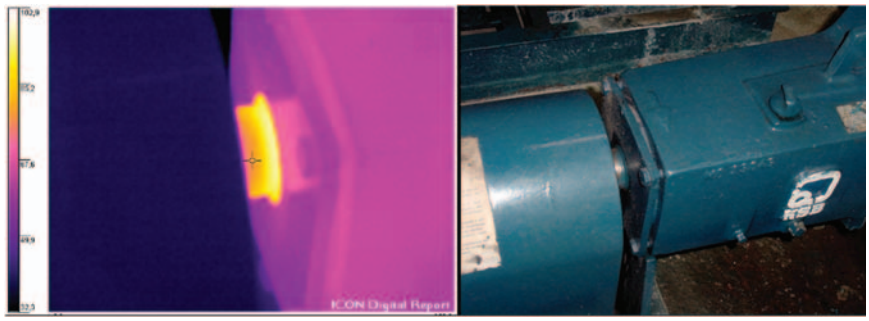
Failed components typically look cooler than similar, normally functioning ones. The most common example is probably a blown fuse. In a motor circuit this can result in a single phase condition and, possibly, costly damage to the motor.

Examples

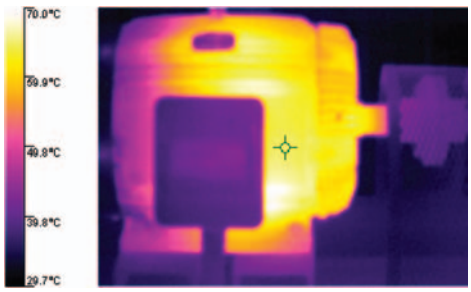
This thermal image shows a drive cabinet with hot connections on both A and B phases. The exact cause can't be determined solely from the image, although it may be a load or balance issue.



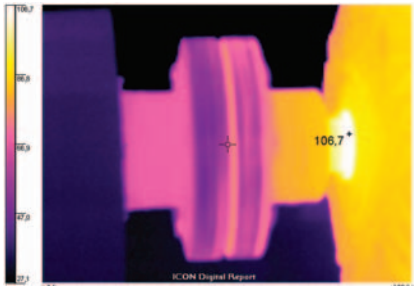
This image shows a warm bearing (or seal) on the pump. Clearly the access is tight but we can still compare the bearing to the housing around it.



This image shows another bearing problem with heat also transferring into the coupling on the right side.



This image shows the motor itself heating up, due to reduced airflow or, more probably, to misalignment.



About insulation resistance testing

Insulation problems on motors and drives are usually caused by improper installation, environmental contamination, mechanical stress or age. Insulation testing can easily be combined in with regular motor maintenance, to identify degradation before failure, and during installation procedures to verify system safety and performance. When troubleshooting, insulation resistance testing can be the missing link that enables you to get a motor back into operation the easy way, by simply replacing a cable.

Insulation testers apply a dc voltage across an insulation system and measure the resulting current. This allows them to calculate and display the resistance of the insulation. Typically, the test verifies high insulation resistance between a conductor and ground or high insulation resistance between adjacent conductors. Two common examples include testing motor windings for insulation from the motor frame and checking phase conductors for resistance from bonded conduit and enclosures.

Insulation multimeters combine the insulation resistance functions above with the other tests needed to investigate motor, drive, and electrical trouble, from basic supply measurements to contact temperature. The key difference is that insulation resistance tests are performed on de-energized systems, while electrical tests (and thermal) are almost always performed on live, operating systems.

Electrical and insulation resistance tests on motors

1. Visual inspection

First, look for a reason NOT to energize. Remove power from the motor and starter (or drive), following lockout/tagout procedures, and disengage the motor from the load.

- Conduct a visual, smell, and heat inspection, interview the client and check the nameplate. Look for loose connections at the starter and check all fasteners.
- Use a DMM to check the supply voltage, then the voltage starter contacts.

Don't risk a fire from a possibly shorted motor. If the supply is good, then there's a motor problem.

2. Control contacts check

Next, check the control contacts for quality of contact:

1. Lockout and tagout the disconnect to the starter.
2. Manually engage the starter, so the contacts close.
3. Set the insulation tester to the low ohms range.
4. Measure the resistance across each set of contacts.
5. The reading should be nearly zero. If it's higher than 0.1 ohms, that set of contacts needs to be replaced.

3. Resistance of line and load circuits to ground

Then, measure the insulation resistance of the line and load circuits to ground. However, **before doing ANY insulation resistance testing, you MUST isolate any electronic controls and other devices from the circuit under test**. Then:

1. Lockout and tagout the disconnect to the starter.
2. Set the insulation tester to the appropriate test voltage (250, 500 or 1000 V).
3. Identify the resistance between these points:
   - Line side of starter to ground
   - Load side of starter to ground

To pass these tests, the line and load circuits need to show high resistance. **As a general rule, AC devices need a minimum 2 megohms to ground and DC devices need 1 megohm to ground to ensure safe operation.**

Note: Different companies have different threshold minimums for insulation resistance on used equipment, ranging from 1 to 10 megohms. Resistance on new equipment should test much higher—from 100 to 200 megohms or more.

If the load side resistance values are acceptable then proceed to the next test. If they aren't, then start tracing the problem: is the insulation breakdown in the load side of the starter, the cables, or the motor?

4. Winding resistance phase to phase and phase to ground

Take insulation resistance measurements phase to phase and phase to ground.

Good results:

- Balanced comparative low resistance values on all three stator phases
- High resistance values on the phase to ground insulation test

Problems:

- Gross resistance deficiencies, such as a phase on phase short.
- Any winding to winding resistance imbalance. If the readings differ by more than a few percent, the motor is probably unsafe to energize.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

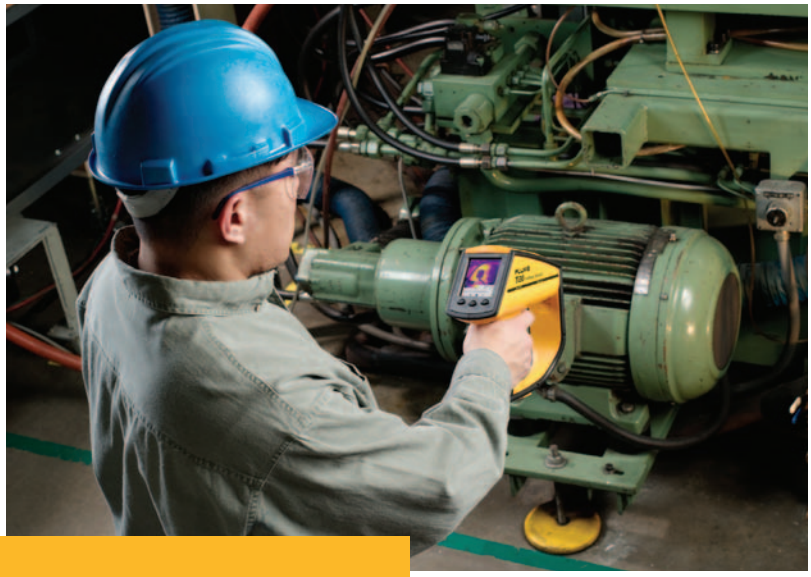
For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 6/2005 2517897 A-EN-N Rev A

FLUKE®

Implementing an infrared thermography maintenance program

Application Note



"I've had training on my Fluke Ti30™ Thermal Imager. Now what do I do?"

John Snell
Snell Infrared

Growing a successful infrared program involves planning and action. You've taken the first steps by purchasing a Fluke Ti30 thermal imager and getting some basic training. This document outlines steps that will help you grow your thermography program into a key part of the way your company does business.

Getting Started

- *Gain support from management*
  Send management a summary of what you learned in thermography training and your ideas for what can happen next. Communicate what you would like in the way of support and find out how thermography performance results will be measured.
- *Practice reading thermographic images*
  Aim for using the camera 2–3 times each week over the next six months to gain expertise. Plan your work, track your findings, and document your results from the beginning.
- *Meet regularly with first level managers, line supervisors and other co-workers*
  Explain what thermography involves, demonstrate the camera, ask for their support and set up a mechanism for them to request thermography surveys. Set up a trophy board of thermal image discoveries to help communicate your program throughout the facility.
- *Integrate with other predictive maintenance efforts*
  Thermography is often part of a larger predictive maintenance (PdM) program. Data from several technologies, such as vibration, motor circuit analysis, airborne ultrasound, and lube analysis can all be used to study the condition of a machine asset. Ideally, these technologies will work from and with the same computerized maintenance management system (CMMS), to access equipment lists and histories as well as to store reports and manage work orders.
- *Establish written inspection procedures*
  Written inspection procedures drive the quality of the data collected and ensure the inspection is done safely. Key ingredients include safety, conditions required, and guidance for interpreting the data.

National Fire Protection Association (NFPA) 70E requires that all personnel be educated about the risks they face when working near electrical equipment. Personal protective equipment (PPE) must also be made available to minimize the risk if an accident should occur. For thermographers, PPE generally includes flash-resistant clothing and a face shield.

As a starting point for creating your specific inspection procedures, review the industry standards that currently exist (see appendix). See if your company has procedures that can be used as a guide and then start with the major electrical and mechanical applications and refine as you develop the program.

Avoid prioritizing findings based on temperature alone. Temperature measurements identify problems extremely well and may help characterize problems, but they aren't the best way determine the cause of a failing component. Your inspection procedures should address the conditions required to locate

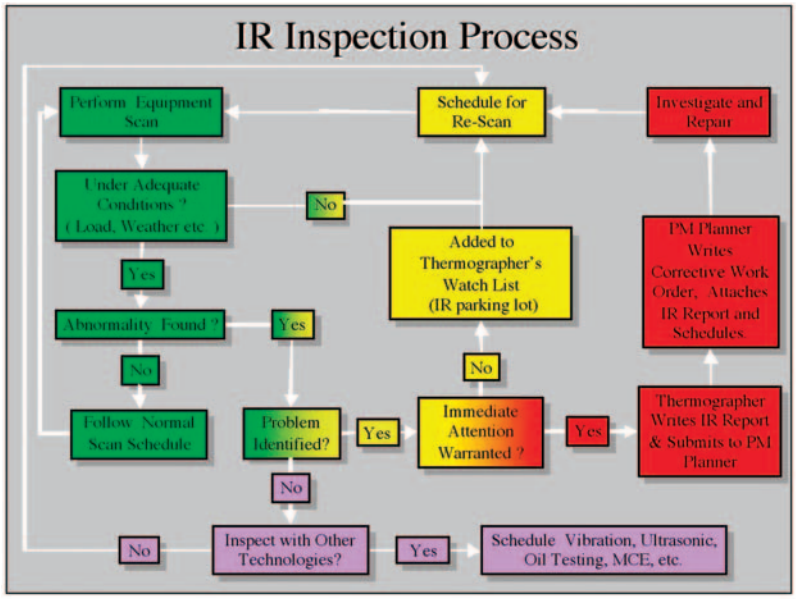
problems, using thermography, as well as acknowledge the other technologies needed to troubleshoot further.

Creating inspection routes

Begin by using existing lists of equipment from a CMMS or other inventory. Eliminate items that aren't well suited for infrared measurement and focus on equipment that creates production bottlenecks. If possible, look at history to guide you; where have failures occurred in the past? Use a database or spreadsheet to group the remaining equipment together, either by area or function, into roughly 2–3 hour inspection blocks.

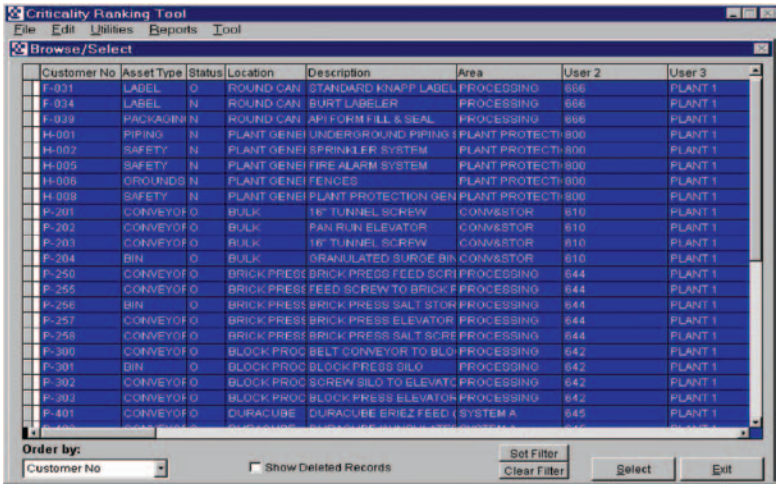
The lists may not be up to date, so you can expect the first inspection cycle to take more time as you locate equipment, update lists, deal with access issues, and so forth. During your first pass, also consider taking digital photos of each piece of equipment and storing the images in the equipment database for later reference as needed.

If thermography is new in your plant, the first few inspection cycles may yield a large number of finds. Subsequent inspections should go more smoothly. After about three cycles, re-organize the routes so they are more efficient and add new routes and equipment into the inspection cycle as necessary. The optimum frequency of inspection will be determined by the needs of the equipment assets. As they age, are heavily loaded, or are poorly maintained, inspections may become more frequent.



This flow chart is an example of how thermography can logically fit into an overall maintenance program that includes other PdM technologies. (Courtesy of Greg McIntosh, Snell Infrared Canada)

Frequency of inspection is based on a number of factors. The key drivers are safety, the criticality of the equipment, the expense of a failure, and the frequency with which problems impact production and/or maintenance. This latter point is important enough that you should devote time to researching past failures, through discussions with co-workers and by reviewing plant records. Once the equipment has gone through several cycles of inspection, you may find the following frequencies are a good target:



Prioritizing existing equipment is essential to getting a successful program started. A database like this one can be sorted according to various parameters as inspection routes are created initially and modified over time. (Courtesy of Management Resources Group)

Equipment type	Frequency of inspection
High voltage substations	1–3 years
Transformers	annually
440V Motor Control Centers Air conditioned	6–12 months
Non-air conditioned or older	4–6 months
Electrical distribution equipment	4–6 months
Large motors*	annually
Smaller motors	4–6 months

** assumes vibration analysis, MCA, and lub analysis are also being used*

It's also vital to inspect all new equipment both as part of the acceptance process as well as, for larger equipment, to establish a baseline. If equipment is damaged on arrival, inspect it as soon as possible to determine its actual condition. Some plants send their thermographers off site to inspect new equipment before it's delivered, often finding deficiencies and problems before the equipment is accepted. When repairs or modifications are made to equipment, the CMMS must alert the thermographer to conduct a follow-up inspection; all too often a repair is not adequately made, for a variety of reasons, so don't assume everything is okay until the follow-up proves it.

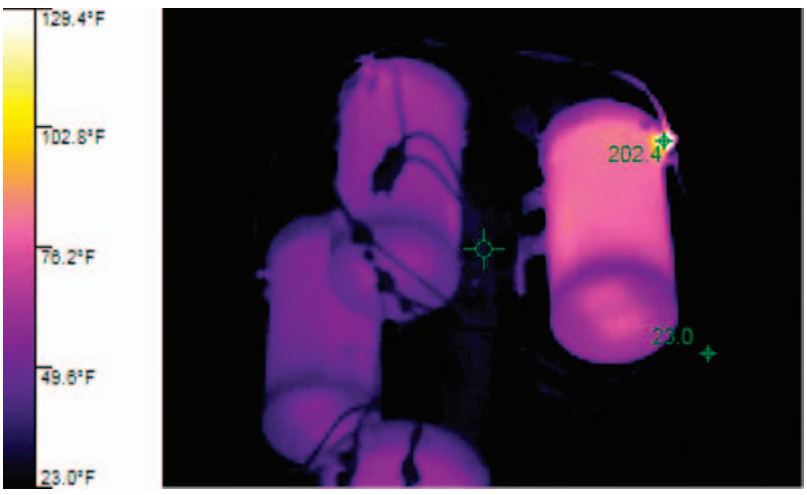
Conditions may not be right for an inspection when it comes due. This incomplete work must be rescheduled before the next cycle, so reserve time for makeup work. You will also develop a list of equipment that needs increased monitoring until it can be repaired; many thermographers add these pieces into a weekly route until the condition changes.

Conducting inspections

Working from a pre-inspection checklist is a good idea.

- Make sure the Fluke Ti30 Thermal Imager is ready to go.
- Charge the batteries.
- Ensure that the system is within calibration by viewing a black body reference or conducting a simple "tear duct check."
- Clear the memory of previously recorded data.
- If you will be following an inspection route that has been inspected previously, upload past results to the camera so they can be compared to new findings.
- If additional equipment is required, such as a digital clamp meter for load reading, or a voice recorder, etc., assemble all of it and make sure it's in good working order.

Sit down with co-workers from the area where you will be conducting your day's work. Discuss concerns (for safety, equipment conditions, etc) and note any unusual conditions that might impact your work. Ask about any problems they have noted. Because routine inspections should generally be conducted by more than one person, this is also a good time to go over your needs with your escort. Typically the escort will locate the exact equipment to be inspected, remove panel covers, take load readings, and watch out for the safety of the thermographer while the Fluke Ti30 Imager is being used. He or she should also be able to fill in any necessary information about equipment conditions or peculiarities. During the pre-job meeting, it's also important to identify the exact person who should be notified if an alarm or emergency condition is encountered.



This finding, an internal fault in a pole-mounted transformer feeding a critical load, was considered serious enough that it could not wait for a scheduled shutdown. Protocols should be established before the inspection to handle situations like these effectively.

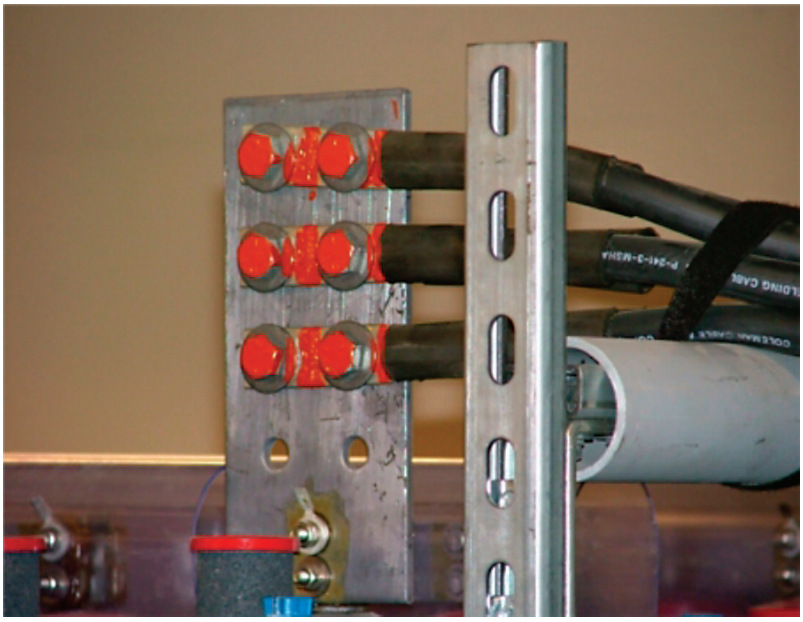
Whenever you enter an inspection area, take a moment to get oriented, determine an emergency exit strategy, and note any potential hazards. Many thermographers begin an electrical inspection by looking first at the panel covers while they are still closed; if any appear abnormally warm it may be appropriate to take further safety precautions before accessing the equipment inside. Airborne ultrasound detection equipment can provide a very useful supplemental signature and a level of assurance that things are safe.

Unless you are conducting a first-time baseline inspection, only record thermal images when problems or "exceptions" are located. Take time to look at the finding from several different angles and collect any other data that might be useful for your analysis, including additional visual images of the component. Don't worry about actually measuring temperatures until after you've found a problem. At that point, if it is appropriate, the correct emissivity and reflected temperature correction (RTC) can be used. Additional analysis is often easier to do back in the office at the computer.

For electrical enclosures, such as an MCC panel, open only as many panels as is safe. If enclosure doors are left open for too long, any problem hot spots may cool off. Once you've completed inspecting an enclosure, the escort should close the cover to ensure the safety of anyone in the area. If necessary, post signs or barricades around an area during the inspection.

When the inspection is complete, meet briefly with the area manager(s) and review your findings. Prepare them for what you'll say in your report, let them know when the report will be coming, and discuss when your next inspection cycle will occur.

Download any data you've collected after each route as soon as possible to reduce the risk of accidental erasure. Delete any unnecessary images and process the rest individually, fine-tuning temperature measurements and making any adjustments to temperature level and span settings. Enter any supplemental data into the



Simple painted markings like theses are often used for high-emissivity "targets" that dramatically increase the reliability of radiometric measurements.

report page, along with the visual image of the equipment inspected.

When the inspection report is complete, add the area manager and/or operator(s) to your distribution list. As a final task, update the equipment list with any changes, additions or deletions.

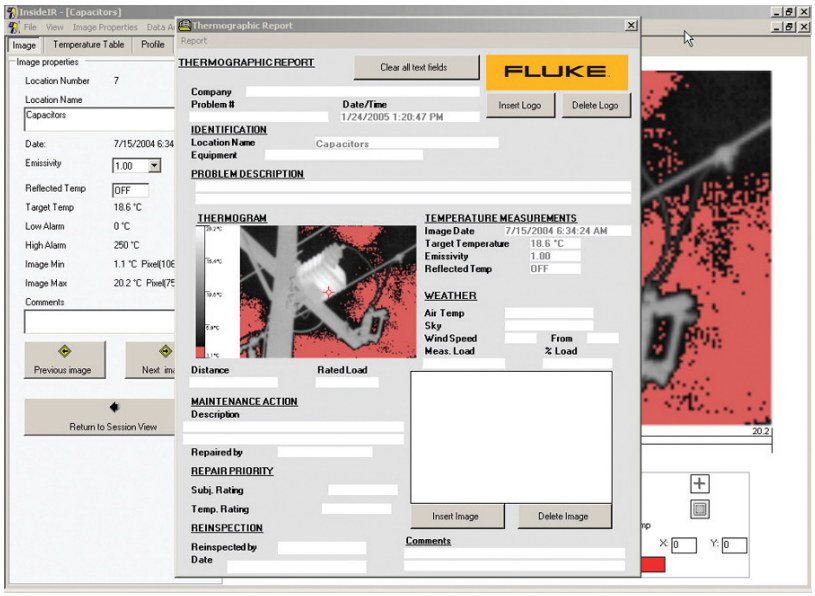
Modifications to improve inspection quality

The following suggestions for modifying plant equipment are designed to make your inspections easier, safer, and more effective.

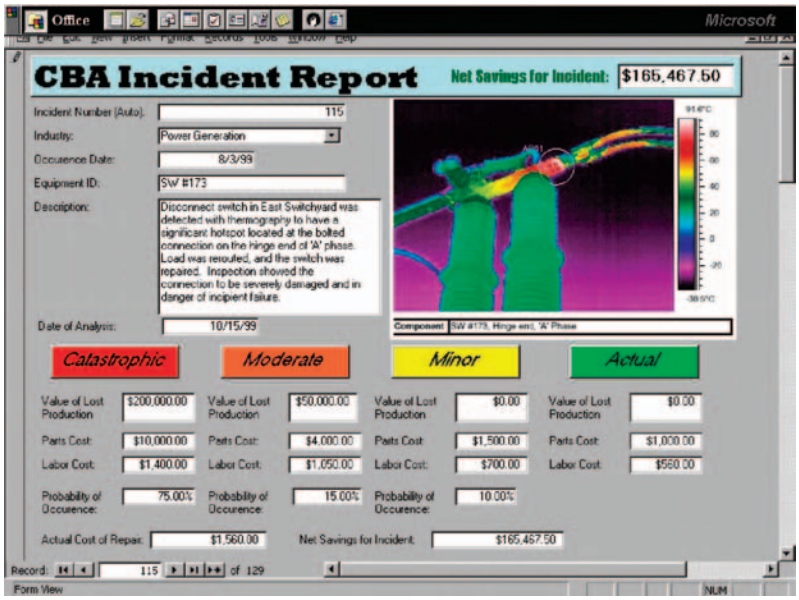
- High-emissivity "targets" installed on such components as bus bars, tubular bus and any large metal electrical connectors can dramatically improve the reliability of radiometric temperature measurements. While there are no standards for how to create such targets, they must be installed while the equipment is de-energized. Many plants have reported good success using spray paint (flat and, if outside, white), especially brands designed to be used on electronic components; electrical tape, and paper stickers. Targets only need be installed near connection points.
- Infrared transparent "windows" (either a crystalline material or a special plastic), installed in electrical panel covers, especially high-voltage, make it possible to inspect the components without opening the enclosure. Only install these in locations that allow for complete inspection.
- The clear plastic, "touch-safe" covers that are increasingly prevalent inside electrical control cabinets are not transparent to infrared! It may be possible to modify these with hinges or, if necessary, routing small holes in them over the connectors and fuse clips.
- Modify equipment guards and covers on conveyance systems and motor couplings so that bearings and couplings can be inspected. Consider installing a small hinged door or using metal mesh instead of solid metal, as long as it doesn't compromise safety.
- Thermal mirrors -- thick sheets of plate aluminum -- can make it easier to see a thermal signature. To view the end bearings of large vertical motors, mount a thermal mirror above and angled down. To view up under a process or machine, place a thermal mirror on the floor.

Reporting results

The software that comes with the Fluke Ti30 Thermal Imager supports simple but useful comparisons of asset condition over time. An alarm temperature can be loaded onto an image before it is uploaded into the camera. During the current inspection, both that alarm setting and the previous image can be used to determine the extent of any changes that might have occurred. The new



Professional reports are easily created using the InsideIR™ software and a PC or laptop.



There are many ways to track the results a program produces. The key is to get buy-in from management as to what indicators are to be used and then to keep up with accumulating the data. The format shown here is clean, simple and powerful in the way it portrays a range of possible savings. (Courtesy of Maintenance Reliability Group, LLC)

thermal image and data document the new condition. This can all be included in a report generated back in the office. Matching thermal and visual images is very useful, and a second thermal image, either a comparison over time or a follow-up image, can also be included.

Clearly identify the equipment inspected as well as the conditions found. Use the area measurement tool showing the with maximum, minimum and average temperatures for the area, rather than the spot measurement tool whenever possible. This will ensure that the true maximum temperature is being identified. It is also important to report the conditions found during the inspection with regard to equipment loading and environmental variables. Note both the emissivity and the reflected background temperature corrections used.

The actual report format can vary widely and can be customized to your needs. If possible, find a way to tie your report into the work order generated by the CMMS so that your findings can be tracked through their useful life.

Once the infrared data is correlated with data from other technologies, the actual operating condition of all assets will be known and can be reported in an integrated form. Those assets that are in an alarm stage (red) or an unknown stage (yellow) can then be scheduled for either repair or further monitoring or managed in some other way, such as reducing load, to minimize the risk of failure. Assets in good condition (green) are ready and available to make your plant profitable. Every machine asset may not be green, but at least you'll know where the problem areas are and can anticipate their condition in the larger picture of plant operations. Reports organized using the green/yellow/red indicators quickly show whether overall plant asset health is improving, a powerful communication to managers.

Key indicators to track your results

Analysis of data over the long term is very important, so plan on accumulating it in forms that facilitate this process. The benefit is twofold. First, you will see trends that may not be obvious in a day-to-day analysis. For instance, you may discover that the motor shop is doing a poor job, or that a certain brand of fused disconnect consistently has problems.

The second benefit is that you will see what's working (or not!) about your program. You'll see where problems are continuing to occur, enabling you to justify dedicating resources in those areas or decreasing the frequency of inspection because few problems are being found. It can also help target maintenance investments and allocation of maintenance funds to get the best returns.

In addition to your measurements, also track increased machine asset availability, production, production quality, and the distribution of maintenance dollars and total maintenance costs over time. Enroll your manager and the maintenance team in tracking this data. The assumption is that if you conduct your inspections on time, perform follow-up inspections, etc., the results will show up in the bigger picture.

Other opportunities

Using thermography to look at other manufacturing process applications can have great value. One thermographer found warm air from the production process blowing directly onto a heat exchanger. Interestingly, the process had shut down repeatedly due to the failure of the exchanger to provide adequate cooling. Engineers had planned to add a larger exchanger to "solve" the problem.

Another thermographer in an automotive assembly plant happened to look at the incoming tires and noticed how cold they were. When he showed the image to the area manager, the two quickly connected this condition to a seasonal problem they'd had for years in which the tires failed to mount properly on the rims. The solution? Bring the tires inside long enough to warm up, a condition documented by another thermal image.

The buildings we work in may also have problems that can solved with thermography. Facilities maintenance can use thermography for roof moisture inspections, locating building

air leakage, analyzing the distribution of conditioned air from HVAC, locating underground drains, pipes and lines, solving comfort related problems in the office workspace, and inspecting battery backup (UPS) for computers systems.

Of course, thermographers looking at processes are not limited to simply measuring temperatures or seeing thermal images. If you take time to correlate them, moisture, thickness, coatings, material type and parts presence will typically all have their own characteristic thermal signature as well. Manufacturing processes are not always simple to look at but doing so can often yield a perspective—Thinking Thermally©—that may be the key to finding solutions to costly problems.

Looking ahead

In summary, now that you have your thermal imager and have been trained to use it, here's what to do next:

1. Communicate thermography plans with managers and operators
2. Integrate thermography into existing predictive maintenance programs
3. Review safety standards and procedures
4. Create an equipment list, schedule and inspection routes
5. Capture baseline images of all critical equipment during first survey
6. Download images after each survey and convert data for tracking
7. Create a report template and distribute results after each survey
8. Set up alarms for image comparison and key indicator tracking over time
9. Modify inspection conditions, lists and routes over time as necessary

By following these steps, you'll develop a successful thermography program that will reduce maintenance costs for your company while improving productivity at the same time.

About the author:

John Snell is a long-time leader in the thermographic industry and the founder of Snell Infrared. He can be reached at (800) 636-9820 or jsnell@snellinfrared.com. More information about thermography and thermographic training can be found at the Snell Infrared web site, www.snellinfrared.com.

Appendix

Thermography Standards

ASTM (ASTM, 100 Barr Harbor Drive,
West Conshohocken, PA 19428–2959; phone 610–832–9500/ fax 610–832–9555)
- *ASTM E 1934, Standard guide for examining electrical and mechanical equipment with infrared thermography:*
- *ASTM E 1213, Minimum resolvable temperature difference (MRTD)*
- *ASTM E 1311, Minimum detectable temperature difference (MDTD)*
- *ASTM E 1316, Section J, Terms*
- *ASTM E 344 Terminology relating to Thermometry and Hydrometry*
- *ASTM E 1256 Standard Test Methods for Radiation Thermometers (Single Waveband Type)*
- *ASTM C–1060 Standard practice for Thermographic Inspection of insulation Installations in Envelope Cavities of Frame Buildings*
- *ASTM C 1153 Standard Practice for the Location of Wet Insulation in Roofing Systems Using Infrared Imaging*

International Standards Organization (ISO) (American National Standards Institute (212–642–4900))
- *ISO 6781 Thermal insulation, qualitative detection of thermal irregularities in building envelopes, Infrared Method*
- *ISO 9712, Nondestructive testing—qualification and certification of personnel*

International Electrical Testing Association
(NETA, PO Box 687, Morrison, CO 80465)
- *MTS–199X Maintenance testing of electrical systems*
- *ATS–1999 Acceptance testing of electrical systems*

National Fire Protection Association (NFPA, PO Box 9101, Quincy, MA 02269; 800–344–3555) www.nfpa.org
- *NFPA 70–B, Recommended practice for electrical equipment maintenance*
- *NFPA 70–E, Standard for Electrical Safety Requirements for Employee Workplaces*

Occupational Safety and Health Administration
- *OSHA 1910*
- *OSHA 1926*

American Society for Nondestructive Testing
(ASNT) 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH www.asnt.org
- *SNT-TC–1A, a recommended practice for the qualification and certification of nondestructive testing personnel*
- *CP–189, a standard for the qualification and certification of nondestructive testing personnel.*

FLUKE®

Ordering information

The Fluke Ti30 Thermal Imager is sold exclusively through authorized thermography distributors. To request a demonstration or order a Ti30 imager, visit **www.fluke.com/thermography** or call (800) 866-5478.

The Fluke Ti30 Thermal Imager, formerly the Raytek ThermoView™ Ti30 Thermal Imager, is now part of the Fluke line of test and measurement equipment.

Fluke. *Keeping your world up and running.*

Fluke Thermography
PO Box 1820, Santa Cruz, CA USA 95061-1820

Fluke Thermography Europe
Blankenburger Straße 135
D-13127 Berlin
Germany

For more information call:

In the U.S.A. (800) 866-5478 or
Fax (831) 425-4561 or
Ti30support@fluke.com

In Europe/M-East/Africa +49 30 478 00 80 or
Fax +49 30 471 02 51 or
Ti30support.de@fluke.com or
International (831) 458-1110 or
Fax (831) 458-1239 or
Ti30support@fluke.com
Web access:
http://www.fluke.com/thermography

©2005 Fluke Corporation. All rights reserved.
Specifications subject to change without notice.
Printed in U.S.A. 2/2005 2435910 A-US Rev A

FLUKE®

Infrared inspecting for building and facilities maintenance

How to find problems lurking behind the scenes

Application Note

Surface temperature can tell you a lot about a building's structural elements, plumbing installations, and HVAC and electrical systems. Problems that are otherwise invisible to the naked eye are suddenly clear as day when you look through an infrared lens. Air leakage, moisture accumulation, blockages in pipes, structural features behind walls and overheating electrical circuits can all be detected and visibly documented with handheld infrared thermometers and thermal imaging cameras. By scanning surfaces with such inspection tools, you can quickly locate temperature variations, which are often indications of underlying problems, and document them with detailed images in reports.

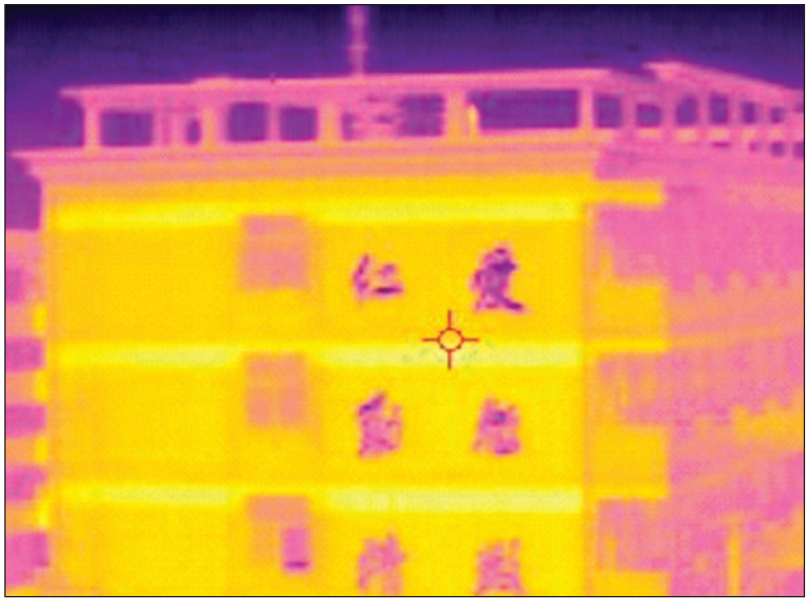
By pinpointing potential sources of problems, you also save valuable inspection time and repair only what needs to be fixed, rather than performing repairs regardless of actual need. Repeated temperature measurements of the same targets can determine whether repairs were successful and help anticipate future repairs.

Simply point, shoot and read

Infrared thermometers measure the infrared energy emitted from surfaces and convert the information into a temperature reading. They are easy to operate – simply point the instrument at the target, pull the trigger and read the temperature value. Because you're measuring from a distance, instead of having to touch the object with a probe, you can check temperatures on operating equipment and in hard-to-reach spaces safely and without special setup. Laser sighting helps you easily mark small targets from optimal distances in low light and in tight spaces.

More than temperature readings

The latest generation of infrared thermometers includes temperature comparison and documentation features to better support your inspection efforts.



Infrared imaging cameras, such as the Fluke Ti30™ Thermal Imager, can identify thermal anomalies within new or existing buildings.

These features include data logging, or the ability to store temperature readings for multiple locations along an inspection route, and audible alarms set by the user to indicate temperatures above and below acceptable ranges.

Looking behind the scenes

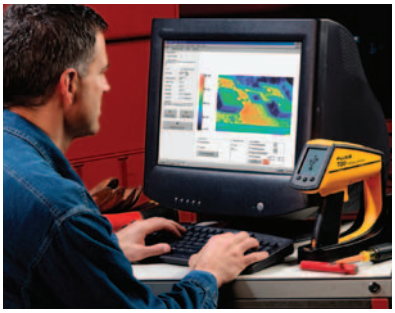
Thermal imaging cameras are another kind of handheld infrared temperature measurement tool. These devices immediately show you the hot and cold spots in the form of thermal images. Traditionally, the high price tag of thermal imagers has been prohibitive, leading many facilities to outsource thermography inspections only once a year. However, new lower cost high-performance cameras make it possible to bring thermal imaging in house. Thermal surveys can identify and establish the extent of thermal anomalies within new or existing buildings, for example:

Inspecting electrical systems: Locate overheating components safely in electrical systems, expressed as hot spots in thermal images. Regular inspections of electrical installations should be conducted at full load to identify potential problems, such as loose connections, load imbalance, and overloads, which, when not attended to, can lead to outages, equipment damage, and safety risks including fire.

Checking for missing and damaged insulation: Inspections both inside and outside structures show you the location, shape and intensity of insulation. Recent amendments to Parts L1 (Dwellings) and L2 (Non-Domestic Structures) of the UK Building Regulations, which came into force in 2002, place particular emphasis on insulation continuity throughout the structure. Key to building conformance is that those responsible for achieving compliance can document that infrared thermography inspections have documented that "insulation is reasonably continuous over the whole visible envelope."

Pinpointing air leakage points: UK Building Regulations also place emphasis on greatly reducing air leakage, or the uncontrolled movement of air into and out of a building, which can compromise the efficiency of building environmental systems. While best

Obtain high-quality thermal images with a simple "click" of the trigger.



Download images and data into the companion Fluke InsideIR software for analysis and reporting.

measured with pressurization testing, thermographic surveys can quickly pinpoint leakage points. Inspections inside and outside of structures, along doors, windows, vents and pipes, immediately show you areas of infiltration and exfiltration.

Finding areas of moisture accumulation: Moisture intrudes through joints and cracks in roofs, ceilings and walls, and is trapped, resulting in structural rot and mold, some of which may represent serious health hazards. Regular thermographic inspections, inside and outside of structures, are therefore critical to quickly locate cold spots, which are often signs of moisture intrusion.

Verifying structural elements: Thermographic inspections can help you quickly locate support beams, pipes, electrical cables, and flues in poured walls, floors and ceilings. Simply scan surfaces, and detailed thermal images clearly show you subsurface details.

Evaluating building materials: Test the performance of interior and exterior wall surfaces, doors and windows under various environmental conditions to determine their ability to retain or reflect heat and cold. A thermal imager will show you energy leaks.

What you need to get started

To perform your own thermal imaging inspections, you'll need:

• Thermal imager with fast scanning speed, sharp image quality, long battery life and on-board storage of several images to enable uninterrupted inspections in the field.

• Software to adjust images, analyze results, and document findings in reports.

• Training on how to use the equipment to get the best results.

In summary, there are a number of reasons why you should add temperature inspections to your building and/or maintenance inspection checklist. Most importantly, thermographic surveys can save you a lot of time and effort in locating existing and potential problems, which can jeopardize not only building performance, but also compliance with building, health and safety regulations.

More information about non-contact infrared thermometry and thermal imaging can be found at www.fluke.com/iaa_imager.

The Fluke Ti30 Thermal Imager provides the lowest total ownership cost for a full-featured, radiometric imager. The package includes all necessary hardware, software and training.

FLUKE®

Ordering information

The Fluke Ti30™ Thermal Imager is sold exclusively through thermography representatives. To request a demonstration or order a Ti30 imager, visit **www.fluke.com/thermography** or call (800) 866-5478.

The Fluke Ti30 Thermal Imager, formerly the Raytek® ThermoView™ Ti30 Thermal Imager, is now part of the Fluke line of test and measurement equipment.

Fluke. *Keeping your world up and running.*

Fluke Thermography
PO Box 1820, Santa Cruz, CA USA 95061-1820

Fluke Thermography Europe
Blankenburger Straße 135
D-13127 Berlin
Germany

For more information call:

In the U.S.A. (800) 866-5478 or
Fax (831) 425-4561 or
Ti30support@fluke.com

In Europe/M-East/Africa +49 30 478 00 80 or
Fax +49 30 471 02 51 or
Ti30support.de@fluke.com or
International (831) 458-1110 or
Fax (831) 458-1239 or
Ti30support@fluke.com
Web access:
http://www.fluke.com/thermography

©2005 Fluke Corporation. All rights reserved.
Specifications subject to change without notice.
Printed in U.S.A. Printed in U.S.A. 2/2005
2436027 A-US-Rev A

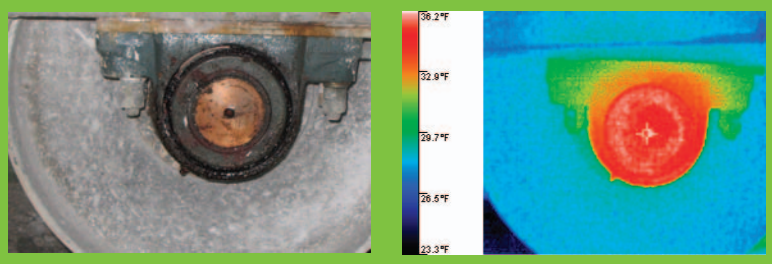
FLUKE®

Inspecting bearings

Application Note

When a motor bearing fails, the motor heats up and lubrication begins to break down. The windings overheat and then the temperature sensor cuts out and stops the motor. Worst case, the shaft binds up, the rotor locks up and the motor fails completely.

Many predictive maintenance (PdM) programs use thermography to monitor the apparent temperatures of operational equipment, using the heat values to detect and avoid equipment loss. By using thermal imagers to capture two-dimensional infrared maps of bearing and housing temperatures, technicians can compare current operating temperatures to benchmarks and detect potential failures.



This overheating shaft and bearing may be an indicator of bearing failure, lack of proper lubrication, or misalignment.

What to check?

Generally speaking, vibration analysis is the PdM technology of choice for monitoring large, accessible, relatively high-speed bearings, but it can only be done safely when transducers can be placed on the bearings. For bearings that are relative small (e.g., in conveyor rollers), in low-speed operations, physically inaccessible or unsafe to get close to while the equipment is running, thermography is a good alternative to vibration analysis. In most cases, thermography can be performed at a safe distance while the equipment is operating. Capturing a thermal image with a handheld imager also takes less time than performing vibration analysis.

Mechanical equipment should be inspected when it has warmed up to steady state conditions and is running a normal load. That way, measurements can be interpreted at normal operating conditions. Capture a thermal image of the bearing to be checked, and if possible, capture images of bearings in the same area performing the same or a similar function, e.g., the bearing at the other end of a conveyor or paper machine roller or another pillow block on the same shaft.

FLUKE®

What to look for?

Problems with bearings are usually found by comparing the surface temperatures of similar bearings working under similar conditions. Overheating conditions appear as "hot spots" within an infrared image and are usually found by comparing similar equipment. In checking motor bearings, this procedure entails comparing end bell to end bell (for motors and bearings of the same type) or stator to end bell temperatures.

In general, it is a good idea to create a regular inspection route that includes all critical rotating equipment. If a route for regular vibration analysis already exists, thermography can be added easily to these existing bearing-monitoring efforts. In any case, save a thermal image of each piece of key equipment on a computer and track your measurements over time, using the software that comes with the thermal imager. That way, you'll have baseline images for comparison. They will help you determine whether a hotspot is unusual or not and help you verify when repairs are successful.

What represents a "red alert?"

Equipment conditions that pose a safety risk should take the highest repair priority. Beyond that, determining when action is required in your facility to keep a bearing from causing the loss of a crucial piece of equipment is an case-by-case undertaking that gets easier with experience. For example, on one difficult-to-monitor line, an auto manufacturer moved from vibration analysis to a combination of vibration and thermography to determine that normal operating temperatures for bearings on the line fell within a specific range. The company's PdM personnel, well trained in thermography, now treat a bearing running above the upper limit of the normal operating range as an "alarm" situation.

When using thermography on bearings not normally monitored using vibration analysis or even when spot-checking bearings, try to follow the lead of the automotive company and establish some "alarm" criteria, as you would for other condition-monitoring technologies. Some thermography experts, for example, have established rules-of-thumb for allowable temperature differentials ((Ts) for bearings on specific types of equipment using specific lubrication techniques (grease, oil bath, etc.).)

What's the potential cost of failure?

For a failed bearing in a specific motor, pump, drive or some other critical component, you can do analysis of the cost of the repair, lost production opportunity and lost labor costs. At one automotive facility, the estimated cost of the failure of a specific pump is more than $15,000 for repairs plus lost production of $30,000 per minute and labor costs of more than $600 per minute. Keeping that pump running is worth the effort.

Follow-up actions

All rotating equipment generates heat at the friction-bearing points in the system – the bearings. Lubrication reduces friction and thereby reduces and to varying degrees (depending upon the type of lubrication) dissipates the heat. Thermal imaging lets you literally "picture" this process while revealing the condition of bearings. When thermal images indicate an overheating bearing, you should generate a maintenance order to either replace the bearing or lubricate it. Vibration analysis or another PdM technology may help you determine the best course of action.

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report, including a thermal image and a digital image of the equipment. That's the best way to communicate problems you find and to suggest repairs.

Imaging tip:

Modify equipment guards and covers on conveyor systems and drive components so that bearings and couplings can be inspected using thermography. Consider installing a small, hinged door or using metal mesh instead of solid metal. In making any of these kinds of changes, be sure not to compromise personnel's safety.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

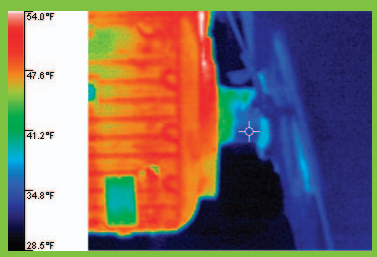
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2519603 A-EN-N Rev A

FLUKE®

Inspecting electric motors

Application Note

Electric motors are the backbone of industry. The U.S. Department of Energy estimates that in the U.S. alone there are 40 million motors operating in industry, and the fact that those motors use 70 % of the electricity consumed by industry indicates their importance.



Properly functioning bearings should show cool temperatures.

A program to avert costly failures in your facility will benefit from including thermal imaging as a condition-monitoring technique for electric motors. Using a handheld thermal imager, you can capture infrared temperature measurements of a motor's temperature profile as a two-dimensional image.

Thermal images of electric motors reveal their operating conditions as reflected by their surfact temperature. Such condition monitoring is important as a way to avert many unexpected motor malfunctions in systems that are critical to manufacturing, commercial and institutional processes. Such preventive actions are important because when a critical system fails, it inevitably increases costs, requires the reallocation of workers and material, reduces productivity and, if not corrected, can threaten corporate profitability and, possibly, the well being of employees, customers and/or clients.

What to check?

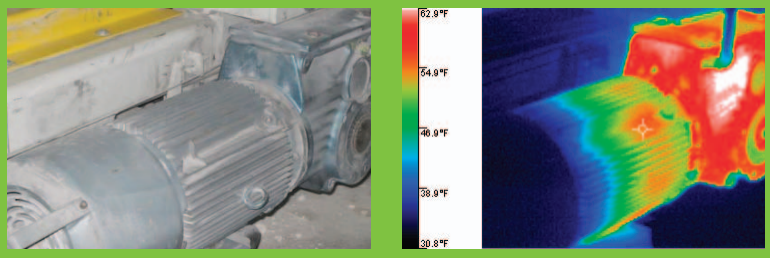
Ideally, you should check motors when they are running under normal operating conditions. Unlike an infrared thermometer that only captures temperature at a single point, a thermal imager can capture temperatures at thousands of points at once, for all of the critical components: the motor, shaft coupling, motor and shaft bearings, and the gearbox. **Remember:** each motor is designed to operate at a specific internal temperature. The other components should not be as hot as the motor housing.

What to look for?

All motors should list the normal operating temperature on the nameplate. While the infrared camera can not see the inside of the motor, the exterior surface temperature is an indicator of the internal temperature. As the motor gets hotter inside, it also gets hotter outside. Thus, an experienced thermographer who is also knowledgeable about motors can use thermal imaging to identify conditions such as inadequate airflow, impending bearing failure, shaft coupling problems, and insulation degradation in the rotor or stator in a motor.

In general, it is a good idea to create a regular inspection route that includes all critical motor/drive combinations. Then, save a thermal image of each one on a computer and track measurements over time. That way, you'll have baseline images to compare to, that will help you determine whether a hotspot is unusual or not, and, following repairs, to help you verify if the repairs were successful.

For more information on Thermal Imagers go to **www.fluke.com/thermography**



This thermal image shows a cool motor on the left and a hot gearbox on the right, with an especially white-hot anomaly.

What represents a "red alert?"

Equipment conditions that pose a safety risk should take the highest repair priority. After that, consider that each motor has a maximum operating temperature that usually appears on its nameplate and represents the maximum allowable rise in temperature of the motor above ambient. (Most motors are designed to operate in ambient temperatures that do not exceed 40 °C.) Generally speaking, each 10 °C rise above its rated temperature cuts a motor's life in half. Regularly scheduled infrared inspections of electric motors identify motors which are starting to overheat. Even an initial thermal image will reveal whether a motor is running hotter than a similar motor doing a similar job.

What's the potential cost of failure?

For a specific motor, you could do an analysis based on the cost of the motor, the average amount of time a line is down from a motor failure, the labor required to change out a motor, etc.

Of course, productivity losses from downtime vary from industry to industry. For example, lost production from a papermaking machine can be as much as $3,000 per hour while in the steel casting industry losses can be as high as $1,000 per minute.

Follow-up actions

If you suspect overheating is the result of one of the following, consider the action described:

a. **Inadequate airflow.** If a brief shutdown is possible without affecting the plant process, shut off the motor long enough to perform minor cleaning on the air intake grills. Schedule a thorough motor cleaning during the next planned plant shutdown.
b. **Unbalanced voltage or an overload.** The usual cause, a high-resistance connection in the switchgear, disconnect, or motor connection box, can usually be pinpointed by a thermographic inspection and confirmed using a multimeter, clamp meter or a power quality analyzer.
c. **Impending bearing failure.** When the thermal images indicate an overheating bearing, generate a maintenance order to either replace the bearing or lubricate the bearing. While somewhat expensive and requiring an expert, vibration analysis can often help you determine the best course of action.
d. **Insulation failure.** If it will not too greatly impact production, de-rate the motor in accordance with NEMA standards. Generate a work order to replace the motor as soon as possible.
e. **Shaft misalignment.** In most cases, vibration analysis will confirm a misaligned coupling. If a shutdown is possible, dial indicators of laser-alignment devices can be used and the misalignment can be corrected then and there.

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report that includes a thermal image and a digital image of the equipment. It's the best way to communicate the problems you found and the suggested repairs.

An imaging tip:

Sometimes it is difficult to get a direct view of the component you want to inspect, such as a motor or gearbox mounted high up on the top of a machine. Try using a thermal mirror to see the *reflection* of the component. An aluminum sheet (1/8-in. thick) works very well. Either **carefully** slip it temporarily into place or mount it permanently in a location that facilitates your inspection. The aluminum does not have to be highly polished to be effective. However, if you are trying to secure true (as opposed to comparative) temperature readings, you must learn how to "characterize" the mirror and adjust your emissivity readings accordingly. For this technique to work, the surface of the mirror needs to be clean, since oil and other coatings will alter the reflective properties of the mirror.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

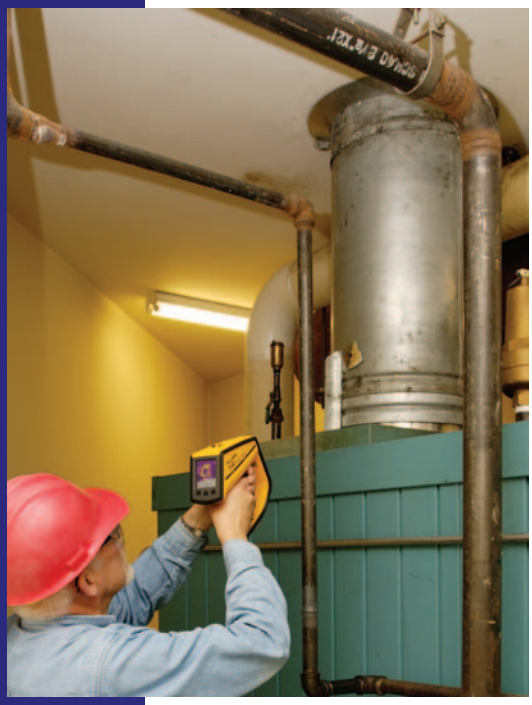
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2519596 A-EN-N Rev A

FLUKE®

Inspecting steam systems

Application Note

According to the U. S. Department of Energy (DOE), more than 45 percent of all the fuel burned by U.S. manufacturers is consumed to raise steam. “Steam is used to heat raw materials and treat semi-finished products. It is also a power source for equipment, as well as for building heat and electricity generation. But steam is not free. It costs approximately $18 billion (1997 dollars) annually to feed the boilers generating the steam.”



Generally speaking, steam is a very efficient way to transport heat energy because the amount of latent heat required to produce steam from water is quite large, and steam is easily moved in pressurized piping systems that can deliver that energy at manageable costs. When steam gets to its point of use and gives up its latent heat to the environment or to a process, it condenses into water, which must be returned to the boiler for re-conversion to steam.

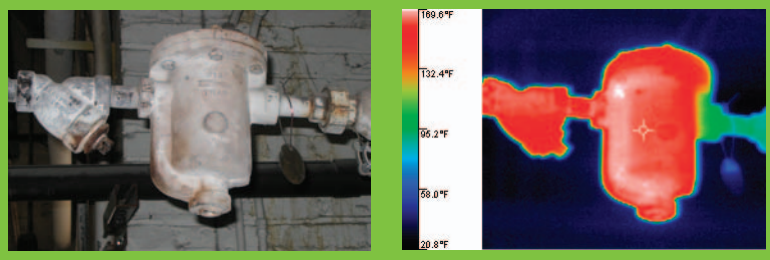
Several condition-monitoring technologies are useful for monitoring steam systems to determine how well they are functioning. Among those technologies is infrared (IR) thermography, in which technicians use thermal imagers to capture two-dimensional images of the surface temperatures of equipment and structures. Thermal images of steam systems reveal the comparative temperatures of system components and thereby indicate how effectively and efficiently steam system components are operating.

What to check?

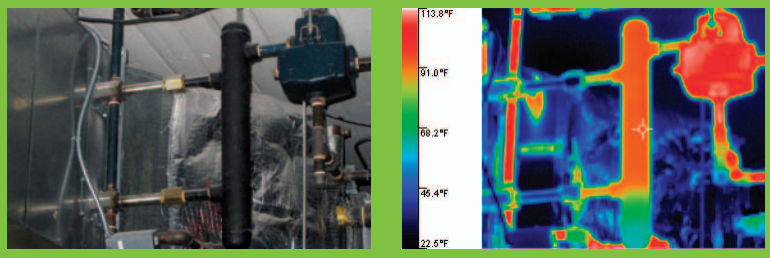
Using a combination of ultrasound and thermal inspections significantly increases the detection rate of problems in steam systems. Check all steam traps and steam transmission lines, including any underground lines. In addition, scan heat exchangers, boilers and steam-using equipment. In other words, examine every part of your steam system with a thermal imager.

What to look for?

Steam traps are valves designed to remove condensate as well as air from the system. During inspections, use both thermal and ultrasonic testing to identify failed steam traps and whether they have failed open or closed. In general, if a thermal image shows a high inlet temperature and a low outlet temperature (< 212 °F or 100 °C), that indicates that the trap is functioning correctly. If the inlet temperature



When operating correctly, as in this example, steam trap thermal images should show an abrupt change in temeperature.



This image shows the steam feed, into the HVAC duct. The feed tube shows condensation in the bottom of the vertical tube.

is significantly less than the system temperature, steam is not getting to the trap. Look for an upstream problem—a closed valve, pipe blockage, etc. If both the inlet and outlet temperatures are the same, the trap probably has failed open and is "blowing steam" into the condensate line. This keeps the system operating but with significant energy loss. Low inlet and outlet temperatures indicate that the trap has failed closed and condensate is filling the trap and the inlet line.

Also use your thermal imager while your steam system is operating to scan: **Steam transmission lines** for blockages, including closed valves, and underground steam lines for leaks, **heat exchangers** for blockages, **boilers**, especially their refractories and insulation, **steam-using equipment** for any anomalies and **recent repairs** to confirm their success.

Consider creating a regular inspection route that includes all key steam-system components in your facility, so that all traps are inspected at least annually. Larger or more critical traps should be inspected more frequently, as the potential for loss is greater. Over time, this process will help you determine whether a hot or relatively cool spot is unusual or not and help you to verify when repairs are successful.

What represents a "red alert?"

Steam is very hot and often transmitted at high pressure, so any condition that poses a safety risk should take the highest repair priority. In many situations, the next most important kinds of problems to deal with are those that can affect production capabilities.

What's the potential cost of failure?

The cost to an operation that completely loses its steam system varies from industry to industry. Among the industries that use the most steam are chemicals, food and beverage processing and pharmaceuticals. Hourly downtime costs for these industries are estimated between $700,000 and $1,100,000 an hour.*

Viewed another way, in a 100-psig steam system, if a medium-sized trap fails open it will waste about $3,000 per year. If your facility has performed no maintenance of steam traps for three to five years, expect 15 to 30 percent of your traps to have failed. So, if you have 60 medium-sized traps on your 100-psig system, losses from "blow by" are likely to be between $27,000 and $54,000 a year.

Follow-up actions

The DOE program for Steam Trap Performance Assessment recommends "sight, sound and temperature" as the dominant techniques for inspecting steam traps. According to their data, implementing a basic annual inspection of the steam traps and associated equipment with infrared inspections will likely reduce steam losses by 50 % to 75 %.

A sensible approach to a steam system management program is to establish repair priorities based on safety, steam/energy loss, and possible impact on production and quality loss.

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report, including a thermal image and a digital image of the equipment. It's the best way to communicate the problems you found and to suggest repairs.

*Source: Washington State Chapter of the Association of Contingency Planners

Reporting tip:

Make room on your report form to schedule a follow-up inspection. This can be something as simple as leaving a blank space labeled "follow-up thermogram" or entering an actual date. Plan your workload so that you can provide a follow-up inspection quickly after repairs have been made. Some thermographers leave the last Friday of the month as a day to do this. It not only gives you a chance to validate the repair, but also to build good will with the crew that did the repair work. More importantly, it gives you a chance to find out what was actually wrong and perhaps even see the damaged components. This is vital to your long-term growth as a thermographer.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

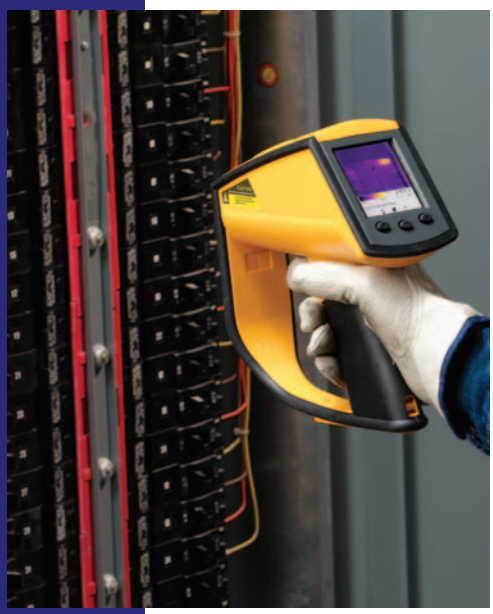
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2519581 A-EN-N Rev A

FLUKE®

Loose or corroded electrical connections

Application Note

Thermal images of electrical systems can indicate the operating condition of the equipment in those systems. In fact, since the beginning of thermography more than four decades or more ago, the principal commercial application for thermal imaging has been electrical system inspection.



The reason thermography is so applicable to the monitoring of electrical systems is that new electrical components begin to deteriorate as soon as they are installed. Whatever the loading on a circuit, vibration, fatigue and age cause the loosening of electrical connections, while environmental conditions can hasten their corroding. Briefly stated, all electrical connections will, over time, follow a path toward failure. If not found and repaired, these failing connections lead to faults. Fortunately, a loose or corroded connection increases resistance at the connection and since increased electrical resistance results in an increase in heat, a thermal image will detect the developing fault before it fails.

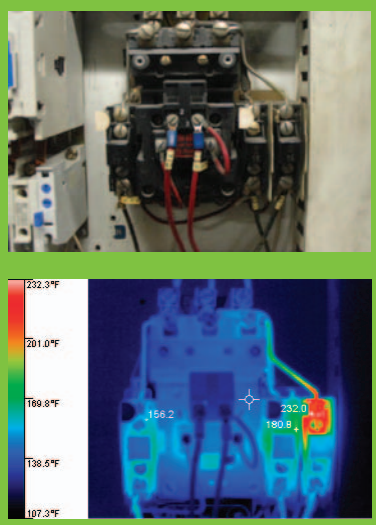
Detecting and correcting failing connections before a fault occurs averts fires as well as impending shutdowns that can be critical to manufacturing, commercial and institutional operations. Such predictive actions are important because when a critical system does fail, it inevitably increases costs, requires the reallocation of workers and material, reduces productivity, threatens corporate profitability and impacts the safety of employees, customers and/or clients.

The following discussion focuses on using thermal imaging to troubleshoot loose, over-tight or corroded connections in electrical systems by comparing the temperatures of connections within panels.

What to check?

Check panels with the covers off and power at ideally at least 40 % of the maximum load. Measure the load, so that you can properly evaluate your measurements against normal operating conditions. Caution: only authorized and qualified personnel using the appropriate personal protective equipment (PPE) should remove electrical panel covers.

Capture thermal images of all connections that have higher temperatures than other similar connections under similar loads.



The connections on this evaporator pump read over 50 degrees hotter on phase C.

For more information on Thermal Imagers go to **www.fluke.com/thermography**

What to look for?

In general, look for connections that are hotter than others. They signal high resistance possibly due to looseness, tightness or corrosion. Connection-related hot spots usually (but not always) appear warmest at the spot of high-resistance, cooling with distance from that spot.

As noted, overheating connections can, with additional loosening or corrosion, lead to a failure and should be corrected.

The best solution is to create a regular inspection route that includes all key electrical panels and any other high-load connections, such as drives, disconnects, controls, and so on. Save a thermal image of each one on the computer and track your measurements over time, using the software that comes with the thermal imager. That way, you'll have baseline images to compare to, that will help you determine whether a hot spot is unusual or not, and to verify repairs are successful.

What represents a "red alert?"

Equipment conditions that pose a safety risk should take the highest repair priority. Guidelines provided by the NETA (InterNational Electrical Testing Association) say that when the difference in temperature (ΔT) between similar components under similar loading exceeds 15 °C (27 °F) immediate repairs should be undertaken. The same organization recommends the same action when the ΔT for a component and ambient air exceeds 40 °C (72 °F).

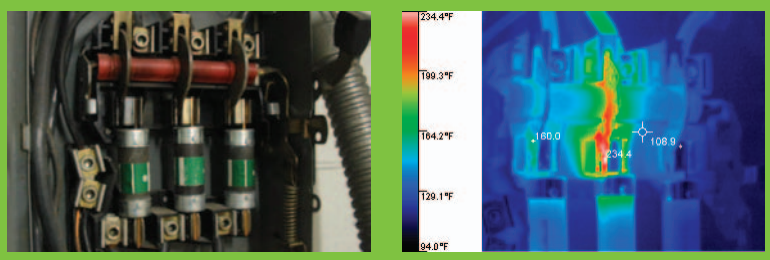
What's the potential cost of failure?

Left uncorrected, the overheating of a loose or corroded electrical connection could blow a five-dollar fuse and bring down an entire production process. Then, it will probably take at least half an hour to shut off the power, get a spare fuse from the storeroom, and replace the blown fuse. The cost in production losses will vary depending upon the industry and the process, but in many industries a half hour of lost production can be very expensive. For example, in the steel casting industry, lost production costs from downtime have been estimated at about US $1,000 per minute.

Follow-up actions

Overheating connections should be disassembled, cleaned, repaired and reassembled. If, after following this procedure, the anomaly persists, the problem may not have been the connection, although a faulty repair remains a possibility. Use a multimeter, clamp meter or a power quality analyzer to investigate other possible reasons for the overheating, such as overloading or unbalance.

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report, including a thermal image and a digital image of the equipment. It's the best way to communicate the problems you found and the suggested repairs.



The temperature readouts show that connections on both phases A and B on this main lighting disconnect are hot, suggesting an unbalanced load.

An imaging tip

Hardware used for electrical connections and contacts is often shiny and will reflect infrared energy from other nearby objects, which can interfere with temperature measurement and image capture. Extremely dirty equipment can also interfere with accuracy. To improve accuracy, wait until the equipment is de-energized and paint dark, less-reflective spots onto the target measurement areas. Be careful not to use combustible materials such as black paper or plastic tape.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2518864 A-EN-N Rev A

Maintenance Routing

Both preventive and predictive maintenance programs rely on periodic inspections of the critical assets that comprise a plant or facility. These inspections range from visual inspections to nondestructive testing performed using a variety of instrumentation. While the methods vary, all inspections require plant personnel to periodically visit each of the systems, machines and/or equipment within the plant.

The logic used to develop the frequency, sequence and actual route used to perform these inspections is critical to the success of the inspection program. The frequency and sequence of inspections should be predicated on the unique requirements of each system and will vary depending on the type of manufacturing or production performed by a plant or the makeup of a facility's equipment.

Normally, these requirements are clearly understood and a concerted effort is made to match them with the specific requirements of plant assets. However, the same level of effort is not normally given to the actual "route" or sequence of inspection tasks that are performed. This oversight has a substantial, negative impact on the efficiency of the recurring inspection process. Without proper planning, the routes used to perform inspections can more than double the man-hours required.

There are three primary criteria that should be considered when developing the routes that will be used to perform preventive/predictive inspections:

Travel Time

Regardless of whether the inspection is visual, or uses instruments such as thermal imagers, the time required to inspect or acquire data is normally substantially less than the time required to move from point to point. Therefore, routes should be developed to minimize the time loss.

In addition to the time lost to travel, excessive elapsed time between inspection points can also reduce the effectiveness of the inspections. Most preventive and predictive inspections rely on single-point sequential data acquisition methods. These methods assume that the relative operating condition, as represented by the temperature, thermal image or vibratione, will remain constant as each of the individual measurements is made. Unfortunately, this is not true and the system's condition is constantly changing. However, when all of the individual measurements are acquired within a reasonable time span, the loss of accuracy is within acceptable limits. Therefore, it is imperative that routes are designed to minimize the time lapse between points, as well as from start to finish of each route.

In some cases, this requirement will force changes in the data acquisition sequence that are less than ideal. For example, acquisition of vibration or infrared data on continuous process lines, such as annealing or papermaking, would ideally acquire data from the drive-side and then operator-side of each process roll. This would require the technician to constantly

move from the operator-side to the drive-side of the line. This would dramatically increase both the interval between measurement points and the total elapsed time to acquire the route. To minimize these intervals, sequential data is acquired from all measurement points on the operator-side and then all points on the drive-side of the line.

Logical Sequence of Inspection

Periodic inspections are performed in an effort to anticipate the need for preventive and/or corrective maintenance. Therefore, the data, including visual observations, should be acquired in a logical sequence that will facilitate this objective. As a rule, the sequence should follow the process. As an example, thermal inspection of a simple centrifugal pumping system should start with the suction supply, i.e. tank, deaerator, etc., and follow the suction piping to the pump, and continue down the discharge piping to reasonable end point. Using this sequence will measure the change in temperature from the source, to the pump; quantify the temperature change within the pump and from the pump to the end of the transfer system. On continuous process systems, such as paper machines, primary metals, printing, etc., the routes should follow the process flow.

Safety

In most cases, the inspector or technician must be in close proximity to operating systems, machines or equipment in order to observe or acquire predictive maintenance data. Therefore, safety must be a primary consideration during route development. Routes should be developed that assure personnel safety as the technician travels from inspection point to inspection point, as well as while they acquire data. When predictive instruments are used, consideration should be given to the methods used to acquire data. For example, most vibration monitoring instruments use a coiled cable to connect a transducer to the data logger. In its relaxed state, this cable forms a loop of about two feet that swings around knee-level as the technician moves from point to point. This loop can easily entangle with moving shafts or other machine components. Special attention should also be given to inspections using fully imaging infrared systems. Most of these instruments use a single-eye viewer that forces the user to look through the eyepiece to acquire thermal images. During these periods, the technician is blind to his or her surroundings. As a result, there is a real potential for injury or worse. When this type of instrument is used, the route must be configured so that the actual inspection point will permit the technician to remain motionless in a completely safe location. The only alternative is the addition of a safetyman that will act as the technician's eyes during the data acquisition sequence.

The routes must also consider the areas to be inspected. In addition to safety concerns pertaining to confined spaces, the remoteness of inspection areas should be considered. A substantial percentage of inspections must be conducted in remote areas, such as basements, behind machinery and other lightly traveled areas. Should an accident occur in these areas, there could be a considerable time lapse before the technician would be missed. In these cases, the route should include either a safetyman or a report-in system that would alert a responsible person if the technician fails to return within a prescribed time.

Summary

Preventive and predictive inspections are essential to effective maintenance management, but they must be performed properly. Careful consideration must be given to ensure that best practices are followed at all times. Even apparently simple things, such as the routes used to sequence these inspections, can and do affect the benefits that will be derived.

FLUKE®

Moisture in building envelopes

Application Note

The presence of moisture in building envelopes, whether from leakage or condensation, can have serious consequences. For example, moisture in insulation reduces its insulating capability, causing heating and/or cooling losses and wasting energy. Moisture can also cause structural deterioration and foster the growth of mold, while a serious roof leak can damage or destroy a building's contents.

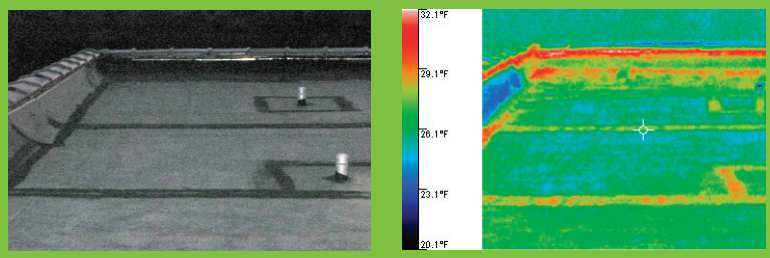
Thermography, also known as thermal imaging, is well suited to identifying wet spots in building envelopes. As a diagnostic technique, thermography captures two-dimensional images of the apparent temperatures of equipment and structures. Thermal images can reveal anomalies in roofs and walls that can indicate the presence of moisture as buildings cool after having been under a thermal load. This happens because water conducts and stores heat better than most building materials. So, when a roof or wall cools, wet or damp areas cool slower than dry areas and show up as "hot spots" on thermal images.

The following discussion focuses on using thermal or infrared (IR) imaging to check for moisture in the envelopes of industrial, commercial and institutional buildings, including moisture in roofs, walls and insulation.

What to check?

Check the outside walls and roofs of buildings after they have experienced a thermal load, e.g. a solar load on a hot, dry day. East-facing walls might be checked in the afternoon and (in the Northern Hemisphere) south- and west-facing walls and roofs after sundown. A significant thermal gradient (15 or 20 %) between the inside and outside is essential in order detect thermal anomalies attributable to the difference in heat capacity between the materials of construction and the additional moisture load.

When potential wet spots in exterior walls and roofs are identified, follow up with an inspection inside the building, to further refine the outdoor findings. Inside inspections can also independently pinpoint moisture in ceilings and walls caused by leaks, water pipe breaks, fire-sprinkler discharges or other water-producing events. Fast action with a thermal imager following a water-producing accident can identify which materials must be dried or replaced.



Cool areas on this roof exposure probably indicate moisture buildup. Mark with tape and investigate with core samples.

FLUKE®

What to look for?

Collecting thermal images is a good first step in analyzing a structure and identifying suspected problem areas. Unlike other moisture-detecting technologies, such as meters, thermography requires no physical contact with roofs, ceilings, walls or floors. In addition, you can check inaccessible areas and cover a large area in a single image.

Regular building-envelope inspections are key to prolonging the lives of industrial, commercial and institutional buildings. New construction and especially new roofs should by thoroughly inspected 6 to 9 months after construction, while the structure is still under warranty. That time lag allows the structure to experience the elements, hopefully a rainy season. Then, perform additional building-envelope scans every two to five years. Compare them to the original, baseline images to establish trends and determine remedies to any deterioration. Experts estimate that preventive maintenance of this kind will double the life your facility's roof. Roof inspections should be conducted with the imager mounted on a tripod, so that the technician can concentrate on properly adjusting the camera to maximize the thermal resolution and analyzing the image.

What represents a "red alert?"

Give any building-envelope condition that poses a safety or health risk the highest repair priority. Next, any roof leaks or moisture conditions that threaten production, electronic data, electronic equipment or the integrity of the building itself should receive immediate attention.

What's the potential cost of failure?

Flat roofs are the parts of commercial, industrial and institutional buildings that are the most likely to fail, and they are expensive to replace. Factors vary so much from facility to facility that it's difficult to put a price on roof replacements, but one expert writing in 1989 came up with a range of weighted averages between $4.50 per square foot for mechanically attached single-ply roofs and $8.00 per square foot for coal-tar built-up roofs.*

Follow-up actions

Before checking your building for moisture, be aware that this kind of inspection constitutes one of the most challenging uses for IR thermography. Buildings vary with respect to kind, use, construction techniques, building materials, size and so on.

*Source: Benchmark, Inc., Roof & Pavement Consultants at 6065 Huntington Ct. NE, Cedar Rapids, IA 52402 — 319-393-9100. The figures are from an article, "Factors Affecting Roof System Costs," by Kent Mattison, P.E.

Conducting effective thermal building surveys requires understanding construction methods and the thermal characteristics of building components, as well as how to account for changing thermal conditions within and around buildings. Then, following the IR inspection, determine where inside heat sources are and whether they affected the exterior images. Finally, perform further analysis to confirm the findings. Infrared inspections provide the most cost effective means of ensuring that the roof is properly sealed, but the presence of a thermal anomaly does not indicate the presence of moisture in the roof. It is essential to follow up with core samples and other techniques. Reference ASTM C1153 Standard practice for location of wet insulation in roofing systems using infrared thermography.

When you have accurately identified moisture in a building's envelope, targeted maintenance work can be performed. If you discovered the problem using a thermal imager, use the software that came with the instrument to document your findings in a report. Include a thermal image and a digital image of the relevant area of the building. Such reports are the best way to communicate the problems you find and to suggest repairs.

Safety tip:

Before starting a roof inspection, review the OSHA safety guidelines. Then, whenever you're up on a roof doing an inspection, have a partner with you—day or night. Some people count on their radios. A radio alone is not good enough. People have died on roofs right next to their radios! Besides, your partner can mark the edges of areas of wet insulation while you scan the roof and make images.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2519615 A-EN-N Rev A

Qualitative vs. Quantitative Inspections

Preventive maintenance inspections, especially thermal inspections thermal imagers and non-contact point infrared instruments can be used to satisfy both the qualitative and quantitative predictive maintenance requirements of most plants. As a rule, the majority of the equipment population of a manufacturing or process plant, as well as most facilities can be effectively evaluated, incipient problems identified and appropriate corrective maintenance tasks identified using relatively simple qualitative inspections. A smaller population of equipment, where specific absolute temperature values are critical, must be evaluated using exact temperature values or quantitative techniques. The majority, i.e., 75% to 85% of these requirements, both qualitative and quantitative, can be satisfied using only thermal imagers or non-contact point infrared thermometers.

Qualitative Inspections

Tracking relative changes in the variables that define the operating condition of critical plant or facility assets is a proven means of scheduling corrective maintenance activities. The vast majority of critical plant systems can be effectively evaluated using this relatively simple, straightforward technique. Petrochemical, electric power generating and a variety of other industries have successfully used this method for more than 50 years. Prior to the development of microprocessor-based instrumentation and computer-based predictive maintenance systems, periodic monitoring was done by simply recording data from installed analog instruments, such as flow meters, pressure gauges and thermometers. As predictive technology evolved, these installed devices were replaced with portable instruments that acquired data from critical assets, uploaded the data to computer-based programs that developed trend charts that plotted the rate of change and projected or predicted when the monitored parameter would reach a level that could result in failure or loss of function of the asset. This type of analysis establishes the acceptable range for each variable and specific alert and alarm limits are designated that determine when corrective actions will be taken. Analysis of condition is limited to the rate that each variable changes and a determination of when it will reach the absolute fault limit when failure is probable.

To be an effective predictive maintenance tool, tracking of periodic measurements of variables, such as temperature, vibration, pressure and other parameters, must be accurate indications of changes in the asset's operating condition. As a result, its value is limited with some predictive technologies. For example, vibration levels vary widely with normal changes in load and process condition of critical process systems. As a result periodic measurement of vibration levels, without normalizing for load-induced changes, is not a viable evaluation technique.

This is not the case with temperature monitoring using infrared technologies. In most cases, the surface temperature at specific points of critical plant assets is a consistent indication of its operating condition. While changes in load, emissivity and other variables may cause a slight change in surface temperatures, these changes are not enough to skew the benefits that

can be derived from the resultant trends and projections of probable failure. Therefore, qualitative analysis of infrared data can be used as an effective predictive maintenance tool.

Quantitative Inspection

A few applications where an infrared or thermal inspection is the dominant technology, are not suitable for qualitative techniques. In these applications, the precise temperature or temperature distributions is an absolute requirement. As a result, the slight variations caused by changes in emissivity, atmospheric conditions and other factors that could distort the readings acquired by the thermal imager or non-contact point thermometer. In these applications, the accuracy needed for effective analysis is critical, and the response characteristics of the instruments used must provide the added accuracy need for proper analysis. In addition, the unit must have the ability to accurately define the spot size of the target object, to avoid distortion in the value measured, due to the environment in the background.

FLUKE®

Thermography and PdM: How to Maximize Your ROI

by

Jason R. Wilbur
Thermography Segment Manager
Fluke Corporation

May 11, 2005

Introduction

Thermography or thermal imaging for industrial plant maintenance applications is a rapidly developing market because:

- the equipment, software and training are becoming more and more affordable,
- the technology is becoming easier to learn and use,
- the applications are intuitive and numerous in an industrial maintenance environment,
- success stories from leading companies are being shared amongst industry professionals,
- and competition amongst suppliers of thermal imaging equipment is heating up.

The great advantage of thermography over some other technologies is that inspections can take place while the equipment is running. In fact, most inspections can only be done with the equipment running. Fortunately, the non-contact nature of infrared also provides an element of safety not found in other inspection techniques.

It is an excellent time to be in the market for thermal imaging equipment. However, companies need to do their homework before making any large investments in equipment, software or training. They must make sure they are investing in the right solutions that will address their needs, and they must make sure that the maintenance program they plan to implement will deliver the return on investment management expects.

The Investment

The challenge with any NDT or PdM technology (thermal imaging, vibration, ultrasound, motor circuit testing, power quality, etc.) is that the initial investment is substantial; typically measured in thousands or tens of thousands of dollars. Without the proper analysis, companies and/or maintenance organizations:

- may decide not to implement a PdM program because they are unable to identify all of the savings, causing them to miss out on operational efficiency improvements,
- may invest in a suboptimal solution that does not best meet their needs,
- may spend significantly more money to establish the program than is necessary,
- and/or may not achieve a return on investment.

Companies need to consider not only the initial equipment costs for the test tools and accessories, but also the software costs, training costs, typical service and calibration costs and overall labor costs associated with performing periodic inspections of critical equipment.

It is very important for companies and maintenance organizations to thoroughly understand their needs. In the case of thermography, companies can spend as little as a few thousand dollars or as much as $1,000,000 to establish an infrared predictive maintenance program. Clearly not every company needs the million dollar solution, but is the $2500 solution really sufficient? Finding the proper balance is the goal.

The Return
The primary objective of any maintenance or reliability manager is to improve operational efficiency. In short, they want to keep things up and running for the lowest possible investment.

Operational efficiency is often measured by labor productivity (both production direct labor and maintenance staff indirect labor), equipment productivity or processing rate, product quality or yield rate and equipment availability or percentage of uptime. In Total Productive Maintenance (TPM) programs, this operational efficiency is often discussed in terms of OEE (overall equipment effectiveness) where:

OEE = % available uptime x % maximum processing rate x % quality yield rate

(NOTE: An OEE = 1.0 or 100% would indicate that the equipment is available 100% of the time, can run at the maximum output rate and never produces a defective product.)

Other measures of operational efficiency include amount of unplanned downtime, inventory turns and average equipment life span.

Regardless of how performance is measured, it is clear that an effective predictive maintenance program using thermal imaging will improve results; especially if the current situation can best be described as "run it until it breaks." By matching the company's predictive maintenance needs and applications to the right thermography solution, companies will achieve maximum return in the shortest period of time. In fact, most companies that have invested in the proper thermal imaging solution for predictive maintenance find that they can achieve payback on their initial investment in well under one year.

Analyzing the Investment

Infrared PdM Needs Analysis
Assessing a company's PdM needs starts with understanding the costs and most common sources of downtime. PdM programs are designed to keep equipment up and running and allow companies to schedule the necessary downtime during periods of production inactivity (off shifts, weekends, periods of slower demand, etc.).

Step one is to identify the most critical equipment in the plant. This can be done through a simple process walk, starting at the beginning (raw material end) of the process and proceeding to the end (finished goods shipment) of the process. Maintenance records and equipment failure data can also help identify those pieces of equipment that are most prone to failure. Evaluating urgent maintenance work orders can also be quite useful, since those "emergency" repair situations are often caused when the most critical equipment in the plant goes down. It is important for the maintenance team to discuss this with the production team. Production/manufacturing often has a very different view of what equipment is most critical to the operation.

Step two is to evaluate what inspection technologies and techniques are available for the critical equipment and the most common failure modes experienced on that equipment. If electrical connections are the most common problem, thermography would be the ideal technology to implement. More importantly, an affordable thermal imager would most likely answer the needs as well or better than the most expensive imagers on the market. If the biggest problem is with high RPM rotating equipment, a combination of vibration and thermal imaging may be in order. The first priority must be to have alignment between the most critical equipment / failure modes and the inspection equipment / technologies that will be used.

Now that the most critical applications for thermography have been identified, it is time to list all of the other possible applications in the facility or company. It is still important to have a sense of priority in the list of possible applications. The applications for thermography are endless, since anything which has a thermal signature can be inspected with a thermal imager. While it would be nice to purchase a thermal imaging solution that addresses every possible inspection need, it may not make sense to spend an additional $50,000 in order to be able to perform inspections that will only occur every three years or where the probability of finding a problem is very small (or just not that important). Also remember, that for a relatively small investment, infrequent or specialized inspections can still be performed by outside consultants who own the more expensive, more versatile and more complex equipment.

Finally, think about possible applications outside of maintenance. Processing plants often have quality control plans based on regular temperature level inspections at critical points in the process. Manufacturing / processing engineers often have applications for thermal imagers in the development of new production processes (plastic thermoforming mold development). The facilities maintenance team may have a desire to complete a thorough roof inspection every other year. Research, development and design engineers also often have a need for measuring temperatures accurately as they develop new products. The advantage of sharing this technology across an organization is that it becomes easier to justify the initial investment, it speeds the payback time and it lessens the budget impact on any single department.

Thermal Imagers

Thermal imagers come in all shapes and size, with various features and benefits and with a very wide range of price tags. Luckily, the process of evaluating imagers is simplified significantly if the critical equipment and applications are known. Some of the key performance specifications for a thermal imager are listed below:

- array size and type (example: 160x120 uncooled focal plane array)
- thermal sensitivity of the array (example: NETD = 200 mK or 0.2 °C)
- optics field of view options (example: 17° x 12.8° fixed)
- optical resolutions or distance to spot ratio (example: D:S = 90:1)
- form factor including size and weight (example: pistol grip form factor, < 1 kg)
- radiometric accuracy (measures absolute, calibrated temperature; example: +/- 2°C or 2%)
- temperature measurement range (example: -10 °C to 250 °C or 14 °F to 482 °F)

- image and data storage capacity (example: internal flash memory stores 100 images and corresponding data)
- battery life (example: five hours in continuous use)
- manufacturer's length of warranty (example: one year)

Array size and type – The larger the array, the more resolution (pixels) in the thermal image. Costs for imagers are directly proportional to the size of the array, since these components contain the core infrared imaging technology. While larger arrays do, typically, produce nicer images, for predictive maintenance customers the picture quality from a 160 x 120 array is more than sufficient in most applications.

Thermal sensitivity or NETD – This is the smallest temperature difference the thermal imaging camera can resolve. 200 mK or 0.2 °C indicates that the camera can resolve two tenths a °C temperature difference. Some cameras can resolve as little as one tenth or half a tenth °C temperature difference. Again, these cameras produce very high quality images, but also, typically, come with a higher price tag. For maintenance applications, there are very few applications, if any, requiring the ability to resolve less than 0.2 °C temperature difference.

Field of view and Optical Resolution –
The optical system in an infrared camera has a limitation to how much the camera will "see" of a given object at a given distance. This is determined by the field of view. If many of the applications involve small objects (< 2 inches in diameter) at large distances (50 or 100 feet), then a narrow field of view (12° x 9°) with a larger D:S (> 250:1) will be required. If many applications are close up looking at large objects (electrical panels in narrow passage ways or building inspections), then a wider field of view (40° x 30°) and smaller D:S (60:1) may be required/sufficient. For most maintenance applications (both electrical and mechanical), a field of view between 16° x 12° and 30° x 22.5° is appropriate; especially if there is flexibility with most inspections to move closer to or farther away from the target. D:S performance of 75:1 or higher is also usually sufficient, although some smaller electrical components may be difficult to measure accurately at this level.

Form factor –
It is important not to underestimate the form factor, size and weight of professional tools. Thermal imagers should be comfortable to carry around and use all day long. They should be well balanced in the hand and easy to grip. They should not be too heavy. The aiming and display angles should feel natural. The buttons, wheels and switches should be easy to access and intuitive to use. This overall ease of use factor could mean the difference between the tool sitting on the shelf or constantly being in use on the factory floor.

Radiometric accuracy –
Some very low cost imagers are non-radiometric or only partially radiometric, meaning the pixels are not measuring an absolute temperature. They are only showing temperatures relative to one another. So while a hot spot might be visible, the camera

cannot tell you what the real temperature of the hot spot is. This is a significant disadvantage in PdM applications, where so much of the equipment being inspected will have rated operating ranges for temperature. Also, trending of temperatures over time is only possible if the imager measures absolute temperature.

Temperature measurement range –
The needs for temperature are a direct correlation to the applications present within the industrial environment in question. In most manufacturing and facilities environments, the temperature range needs for the electrical and mechanical equipment will not exceed 250 °C. However, in the metals industries and some others, temperatures over 250 °C are quite common. If this is the case, a camera with a higher temperature range may be necessary. If the higher temperature requirement is more of the exception than the rule, this may be where an outside consultant can help supplement an internal program. Another option for higher temperatures is to use an infrared filter to reduce the IR energy reaching the detector. This allows the camera to "see" higher temperatures, although the camera may no longer be able to measure accurately those temperatures.

Image and data storage capacity –
Internal memory has some advantages over external options such as memory sticks or flash media cards. The user doesn't have to worry about losing the external memory devices and the user interface is not complicated by selecting the memory location for the camera to use. The important question is whether the camera holds enough images for a full day of testing or will the stored images need to be downloaded to the PC several times each day. In most environments 100 (or even 50) memory locations is sufficient to support a full day of uninterrupted inspections.

Battery life –
Similar to internal memory capacity, battery life is a convenience issue. Does the camera's battery life provide for a full day of uninterrupted inspections? This will require only four or five hours of continuous use battery life (since during a day of inspections, the camera is typically not continuously in use). Is the discharge time faster or slower than the charging time? It should be at least three times faster to charge the battery as it is to discharge, otherwise you will need multiple batteries and chargers, which can be quite expensive. Is there a convenient power option besides a customer rechargeable battery pack? It can often be a life saver if "off the shelf" alkalines can be substituted instead of the custom rechargeable battery pack. With batteries, think convenience, cost and reliability.

Advanced features like voice recording and heads up displays –
For some users, including professional thermographers and consultants, advanced features like voice recording and even heads up displays with Bluetooth technology are considered valuable and well worth the additional investment and added complexity. For a person who is using the camera all day, every day, who has the time to spend learning how to use all of the advanced features and is most concerned about producing a thorough inspection report at the end of the day or week, these features can be beneficial. However, for the person who shares a camera amongst their work group, and who values

simplicity (they won't use the camera if they have to relearn how to use it every time they pick it up) and durability (the more bells and whistles, the more things there are to break), these features tend to be a distraction.

To summarize, it is important for companies to invest in a thermal imaging camera that fits their needs. This means the camera should be appropriate for the majority of their intended applications, but not be over specified or loaded with complicated and expensive extras. These high end specifications and extras will definitely increase the up front investment, so it is important for the decision maker(s) to validate the company's true needs.

Thermal Imager Accessories

Before purchasing a thermal imaging camera, consider the additional accessories that may be needed. Depending on the battery life, extra batteries and charging stations may be needed to get through a full day of inspections. Extra batteries can cost several hundred dollars a piece. Also consider the need for a transport/carrying case. Buying a camera with optional lenses provides a more flexible imaging solution, but it is also significantly more expensive. Make sure the optional lenses are truly needed and will be used. Ideally, the company will receive everything they need in one convenient package, and they will not have to buy lots of extras just to get started.

PC Software for Data Storage, Data Analysis and Report Generation

There are various software solutions available, which accompany thermal imaging cameras. Some software is very basic, only showing images (picture files) with no ability to analyze data or even create a report. Some software will store and analyze data and create reports. Some software will also integrate with other PdM technologies and even automatically generate work orders in the CMMS system. Again, understanding the company's needs is critical to making the correct choice. With some of today's affordable thermal imagers, advanced storage, analysis and reporting software is provided at no additional charge, as part of an overall PdM solution.

For predictive maintenance, having the ability to analyze images and data and create reports is very important. Sometimes, just seeing the image is not enough to make a determination of the existence and/or cause of a problem. Also, advanced software packages provide additional flexibility to the end user while in the field. If the end user sets the wrong emissivity or gets back to their office and wants to see an image in a different palette, this is no problem. They do not have to go back into the field and retake the image. The software allows them to change the image and data settings after the fact, in the comfort, quiet and safety of their office.

Another consideration for software is whether there is a license agreement. Can the software be loaded on unlimited PCs or does the company have to pay a license fee for each additional user?

Also, what about software upgrades? Are they offered periodically, and if so, how much must the company pay to gain access to the new features.

The investment for thermography software can range anywhere from "free" to thousands of dollars for each individual user. Once again, matching the needs of the company / applications with the solution is very important to make sure the investment will generate the maximum return in the shortest period of time.

Training

Training is an important consideration when starting any new initiative or improvement program. Predictive maintenance and thermal imaging are no different. In order to maximize the return on investment in cameras, accessories and software, the engineers, technicians, mechanics and/or electricians must be trained on:

- how to use the equipment
- what applications will provide the greatest return on investment
- the limitations of infrared inspections based on the laws of physics
- how to properly perform inspections to achieve consistent and reliable results
- how to interpret results and generate meaningful reports
- how to safely conduct thermography inspections in an industrial work environment

Some manufacturers of infrared cameras provide free training with the purchase of the thermal imager. This training may only cover the basic use of the camera or it may be more involved, touching on applications as well as best practices for establishing an effective infrared PdM program.

There are also opportunities to send personnel to more extensive training, which will result in a level of certification based on the ASNT standards. Through certification, an employer can ensure that their personnel are fully trained and qualified to perform thermography inspections.

Depending on the sophistication of the PdM program, more or less training may be required. Regardless, it is recommended that companies consider their investment in training prior to launching a new PdM program. Any investment in hardware and software can quickly be lost if people are not properly trained. In fact, an untrained technician performing inspections can actually increase maintenance and operational costs compared with doing nothing at all.

Service and Calibration Costs

Before making any investment decisions in thermal imaging equipment, consider the ownership costs associated with service and calibration over the life of the instrument. There is a very wide range of costs from camera manufacturers for basic service and calibration of thermography equipment. Depending on the brand and model of camera, costs for an annual calibration could be as little as $350 or as much as $2000.

Proactive/Predictive Maintenance Inspection Routing

Finally, once the equipment is in hand, the software has been installed and the training has been done, it is time to actually perform regular inspections of the critical equipment

in a facility. The effort required to establish a PdM program, identify the equipment, determine the inspection techniques and technologies for each, determine the frequency of inspections required and logically plan the inspections in the form of inspection routes is not at all trivial. Once the program is up and running, the effort involved to collect, store, analyze and report on the data is also significant.

It is helpful if the thermal imager being used supports the concept of inspection routing. Some cameras even provide guidance to the user in the field while they are executing an inspection route. It becomes much easier to manage a broad based PdM program if the tools in use are designed such that the actual electricians and mechanics can easily gather the data on their own, freeing the expert to manage the overall program.

Companies should be aware that PdM techniques often, initially, generate more maintenance work than there was before. Electricians and mechanics will be busy not only executing inspection routes but also fixing potential problems or "finds." The workload is very different from a "run it until it breaks" approach. Initially the workload will be greater, but if the program is well designed and executed, very quickly the PdM approach will take less maintenance and production manpower and resources, as the activities transition from reactive to proactive. This will most definitely improve the companies overall efficiency and effectiveness.

Maximizing the Return

The benefits of investing in thermal imaging equipment, software and training and implementing an in-house infrared PdM program include:

- eliminating existing expenses such as annual or semiannual thermographic inspections by outside consultants
- reduction in unnecessary, preventative maintenance activities
- improve maintenance efficiency and reduce unplanned downtime
- reduce capital equipment expenditures by increasing the life expectancy of capital equipment
- improve production efficiency and quality

Eliminating Existing Expenses

Many companies hire external consultants (rates may range from $750 to $1500 per day) to inspect their facilities on an annual or semi-annual basis. Often, this inspection or survey is required by the company's insurance company. Unfortunately, there are some limitations to this approach to thermography:

1. Often, the thermographic report gets filed away and no actions are taken.
2. These reports frequently contain images of every piece of equipment inspected, without effectively highlighting those pieces of equipment that have a real problem or need immediate attention.
3. If and when the problems identified in the report are acted upon, there is no way for the company, without the consultant's help and fees, to verify that the repair actually eliminated the problem.
4. Although the consultant is the one who will capture the images, analyze the data and create the reports, maintenance personnel must typically accompany the

consultant throughout their entire inspection in order to provide access to equipment and identify potential safety hazards, so plant personnel are also involved in these inspections.

5. In order for consultants to reduce their liability, they typically highlight all issues, even if they are marginal problems. It is up to the maintenance team, at this point, to determine what issues really require their attention.

By bringing the inspections in-house, most of the limitations listed above can be eliminated in addition to the consultant fees. Sometimes the consultant may not be eliminated completely but simply paired back to specialized inspections, for which in-plant personnel either don't have the equipment or are not trained. It is clear that, for many companies, simply outsourcing the thermographic inspections on an annual basis to outside consultants is not a solution that will provide the best return on investment.

Eliminating Wasteful Maintenance Practices

Preventive maintenance is based on the idea that regular maintenance of critical equipment will keep that equipment up and running. While this is generally a true statement, often companies are finding themselves investing in manpower and materials to perform regular maintenance on equipment when that regular maintenance really isn't needed. Predictive maintenance techniques are used to assess the "condition" of the equipment before taking maintenance actions. In this way, actions are only taken when the machine's condition warrants the action, not before.

There are even cases where preventive maintenance actions, if taken too soon or too often, can actually lower performance levels. Applying grease to bearings should be done somewhat regularly, but if grease is overdone, the bearings can actually fail prematurely.

Finally, with better tools, maintenance personnel can be more effective and efficient. While a thermal imager is considered the ideal tool for predictive maintenance, it is also very useful simply as a troubleshooting tool. When rotating equipment seems overloaded or is too noisy, inspecting the equipment with a thermal imager can quickly help the user to identify a heat signature and more importantly a source. Many electrical problems can also be more quickly identified with the help of an imager.

Finally, safety is also an important benefit when using a thermal imager. Because thermal imaging is a non-contact technology, users can stay out of harms way while inspecting "live" or "rotating" equipment.

Improving Maintenance Efficiency

As with any predictive maintenance technology, the ultimate goal is to keep equipment up and running. This means we must reduce the amount of unplanned downtime. Unplanned downtime leads to many problems for a production facility:

- maintenance personnel must drop whatever else they are working on to address the unscheduled down time

- often equipment that fails unexpectedly is very expensive to fix versus if maintenance had intervened before catastrophic failure had occurred
- overtime costs increase when downtime events are unscheduled
- customer orders are shipped late
- revenue may be lost forever to the competition, depending on the product (often true for commodities)
- production quality and yields decline
- scrap increases as the production process unexpectedly stops (especially true in processing industries)
- the need to carry additional spare parts and maintenance inventory just in case equipment unexpectedly fails

Each of these problems has a very real cost associated with it. The productivity of maintenance personnel is generally stated in terms of labor hours saved and an average labor rate. With fully burdened (including benefits and overhead) labor rates ranging anywhere from $40 to $100 per hour for maintenance personnel, the savings from productivity improvements can quickly add up. Add on overtime that inevitably increases as unplanned downtime increases (both for maintenance and production personnel) and improved maintenance practices can have a dramatic impact on labor costs.

Most problems become much more difficult and expensive to repair after they have catastrophically failed, versus if maintenance personnel had intervened sooner. Fortunately for owners of thermal imaging cameras, most problems associated with electrical and mechanical systems generate heat well before catastrophic failure occurs. Often, parts that cost pennies, if identified early enough, can be replaced in time to prevent damage to equipment that costs thousands of dollars.

Production is impacted heavily by unscheduled equipment failures. Production personnel are unable to continue producing product. Unreliable equipment lowers yields resulting in rework and scrapped material. If the plant is running at capacity in order to meet the demands of the market, then downtime will cost them customers, revenue and profits. For companies that have been operating under the “run it until it breaks” maintenance philosophy, they must have stockpiles of replacement and backup equipment inventory, so that downtime can be minimized. Investing in idle inventory not only takes cash out of the business, but it also involves ongoing costs to store, organize and manage. Companies generally estimate annual inventory carrying costs at between 10% and 25% of the inventory’s value. If there is $100,000 worth of spare parts or back up equipment inventory, it is costing the company somewhere between $10,000 and $25,000 per year to maintain that inventory.

Many process plants and manufacturing companies track downtime very closely and know precisely how much an hour of downtime costs them. This can vary widely by industry (anywhere from a few hundred dollars to tens of thousands of dollars per hour). Obviously, the higher this number, the more effort and investment companies will put into predictive maintenance.

Reducing Capital Expenses
The final benefit to consider when implementing infrared predictive maintenance is simply the increased lifetime of capital equipment that can be achieved. If the average life time of equipment for a company is 10 years and the total value of that capital equipment is $1,000,000, then the company is, on average, spending $100,000 per year to replace aging equipment. If the average lifetime can be extended by 10% due to improved maintenance practices, then the annual costs to replace aging equipment drops to $90,000 per year, saving $10,000 each year in replacement costs.

Another advantage to incorporating thermography into the maintenance tool box occurs when new equipment is purchased and installed. Many companies use thermography to verify the proper installation of new production lines, furnaces, motors, electrical distribution systems, substations, etc. It is always more cost effective to find problems with equipment when it is new, and still under warranty, then once the warranty has expired. Also, equipment is not always installed properly, which can turn a properly running piece of equipment into a failing piece of equipment very quickly.

Conclusion

The primary objective of any predictive maintenance program is generally to improve operational performance. Produce more and higher quality products, on time, with less cost while generating more profits. Any actions or programs that don't generally support this primary objective will quickly fall out of favor with management.

With the proper knowledge and tools, maintenance and reliability managers can easily justify the implementation of an infrared predictive maintenance program. A thermal imager with the necessary accessories, PC software for storage analysis and reporting and professional thermography training form the critical components to any effective infrared predictive maintenance solution.

Before making any investments in thermography, companies should thoroughly assess their critical equipment, applications and organizational needs. Only then, should they investigate the products and solutions available. The market is changing rapidly and products are becoming more affordable all the time. A few years ago, to begin a new infrared PdM program might require an investment of $50,000 or $100,000. Today a company can get started for under $10,000.

Once the right solution has been identified, often lower and mid level managers must sell the investment decision up the chain. Even at the $10,000 investment level, most companies required several approvals. Approvals are more likely, if the discussion is based in a solid Return on Investment Analysis. One must be realistic about the costs of starting an ambitious infrared PdM program. Most good managers will quickly see though any efforts to sugarcoat the initial investment requirements. Fortunately, for most companies, the benefits of an effective PdM program far outweigh the up front investments required. Whether it is the elimination or reduction of annual or semiannual thermographic inspections by outside consultants, the reduction of unnecessary

maintenance activities, the elimination of unplanned downtime, the increase in life expectancy for critical capital equipment or the improvement in production productivity, quality and delivery, there are plenty of financial reasons to justify an investment in thermal imaging for predictive maintenance.

FLUKE®

Tests and measurements for electrical fire prevention

Application Note

For the most part industrial and commercial electrical systems are getting safer and more reliable. The U.S. Fire Administration's most recent report, analyzing data from 2001, estimates that 8.7 % of the nation's 47,785 non-residential fires were caused by electrical distribution equipment. That's 32 % fewer than in 1998.

Use thermal imagers to check energized components for hot, loose or corroded connections.

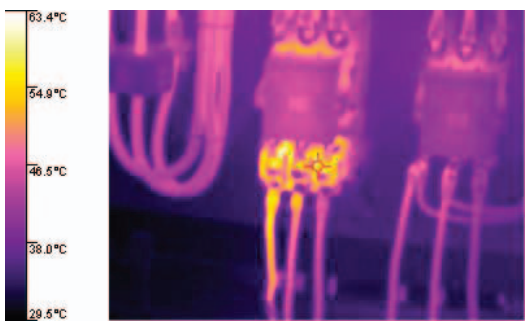
Strict building codes, high-quality equipment, good system design, competent installation and professional maintenance are all factors in driving the downward trend. Still, this translates to 4,157 commercial, industrial and institutional buildings struck by electrical fires in 2001.

Commercial, low-voltage systems contain many sub-systems: switchgear, transformers, panels, receptacles, motor controls and lighting, to name a few. Common to all of these components are connections, insulation and overcurrent protection. Failures of these fundamental mechanisms are at the root of many electrical fires and are the target of many electrical maintenance procedures.

NETA Maintenance Testing Specifications and NFPA standard 70B Recommended Practice for Electrical Equipment Maintenance list procedures for testing the various components of an electrical distribution system. Thermographic testing is covered by ASTM E 1934 Standard Guide for Examining Electrical and Mechanical Equipment with Infrared Thermography.

Many of the tests aimed at preventing electrical fires also address reliability and safety, so a good testing program can deliver all three. In fact, many industrial insurance companies require evidence of a regular electrical testing program.

This article reviews the fundamental causes of overheating, as well as, the tests and tools commonly used to uncover overheating problems.



Thermal image of a loose terminal contact.

Root causes of overheating in electrical systems

Combustion requires both heat and fuel. Designers of electrical equipment are careful to use fire-resistant materials, making the electrical system a poor provider of fuel. The fuel for the fire usually comes from some nearby material, with the electrical system providing the heat required for ignition.

Heat is a normal byproduct of the flow of electric current. The National Electrical Code takes heat into account and provides rules for building a safe electrical system. So how can an electrical system that was designed and built to comply with the NEC still cause a fire?

Poor connections. Vibration or thermal stress can cause connections in power distribution systems to loosen. Contamination can corrode connections. Both factors increase the resistance of the connection. All terminals and splices are potential candidates for overheating, although the more current a connection carries, the more critical it is to maintain low resistance. Consider that if a connector in a 50 amp system presents just 0.1 Ohms of resistance, it will dissipate 250 watts at the interface of the connection! Furthermore, if the condition is allowed to persist, oxides will build up on the connection interface, causing the resistance to increase. Ultimately this can result in what is called a "glowing connection", which can generate significant heat without tripping protection devices.

Loose connections that periodically "make and break" can also cause series arcs. Arcs are electrical discharges across an air gap. In this case the arc is generated across the small gap between conductors as the connection opens repeatedly. The resulting heat is very focused and may lead to insulation failure or fire if a combustible fuel source is nearby.

Switches, relays and circuit breakers are also forms of connection. They are designed to open and close repeatedly without overheating, but they are subject to the influence of vibration, heat, and contamination just as any other connection.

Insulation failure. One of the reasons that electrical fires are less common is that the quality of insulation is better than in the past. But any insulation system will still degrade with age, heat and contamination.

The most extreme form of insulation failure is a short circuit. In this case, two conductors make contact and remain in contact. The resulting overcurrent should cause a fuse or circuit breaker to open. But if the overcurrent protection device fails to open, the circuit upstream of the short circuit will be subject to overheating.

If there's a ground fault (a short circuit involving an equipment ground), then the breaker should also open. If it doesn't, the same overheating arises. If there's a resistive connection in the bonding system that limits the current, the resulting current may not be sufficient to trip the upstream protection devices but may still cause heating in the bonding system.

Parallel arcing occurs when two connectors come close, or touch and part. It has similar characteristics to series arcing (above) but tends to involve higher currents. This can cause ignition of a nearby fuel source or further degradation of the insulation. Arcing can discharge hot metal sparks that can ignite a nearby fuel source.

If insulation is subjected to the heat of other failures, the surface of the insulation can char and become conductive. A phenomenon called arc tracking can result, causing intense localized heating similar to other arcing.

Lightning. One of the functions of the ground system is to provide a low impedance path to earth, allowing a lightning strike to pass with as little damage as possible. Surge suppressors rely on a good ground path to operate effectively. Periodic testing of the ground system and the resistance between the ground electrode and earth helps to insure that this system will work when it needs to.

Harmonics. Most of the current that flows in a US electrical system cycles at 60 Hz. Harmonic currents contain higher frequency components that generate heat throughout the system. Harmonic distortion is present in any electrical system that supplies electronic loads like motor drives, computers, control systems or production machines. Extreme distortion and heavy loading can cause overheating in electrical equipment, especially in older distribution systems.

The third harmonic is caused by single-phase loads like computers and other office machines. This harmonic adds in the neutral in a 3-phase system and can cause the neutral conductor to overheat if it is too small.

Avoid electrical shorts by testing the insulation resistance on cabling.

Periodically examine power quality for voltage sags, harmonics and other causes of overheating.

Overloading. If a load draws too much current, the system components upstream of the load have to carry that current. The main protection against overload is the overcurrent protection device which should open. If it does not open, the high current will cause overheating distributed along the portion of the system upstream of the excessive load.

Wiring mistakes. The electrical system in commercial buildings is a dynamic entity. Over time, tenants change, production lines move, and new equipment gets installed. In a time crunch, mistakes are common and although a system may operate just fine for a while, latent problems can be created.

A potential fire hazard exists when someone "upsizes" a protection device without changing the wire size. For example, simply replacing a 20 amp circuit breaker with a 30 amp circuit breaker could allow existing 12 AWG wiring to carry excessive current. A similar situation occurs any time someone connects a smaller gauge wire to a circuit with higher ampacity.

Using one neutral conductor as a return path for more than one phase conductor will enable loads to function but can easily overheat the "shared" neutral conductor.

Tests and measurements for detecting heat and failing components

The trick with detecting electrical fire hazards is knowing what an abnormal reading looks like. The best solution is to gather baseline readings for especially important components and equipment. That gives you a point of comparison. Then, make a habit of performing these tests once a year. That will spot other kinds of failures in the works, as well, yielding predictive maintenance cost savings as well as fire prevention.

Here are the most common tools and measurements that testing professionals use to check for overheating or an inclination towards overheating.

Visual inspection. Electricity may be invisible, but the effects of heating on metal and insulators are not. Discoloration or charring is a sure sign that components are overheating. Also be alert for smells, like an overheating component would produce.

Thermography. Thermal imagers can read the infrared energy emitted by an object and create a visible image of the object's surface temperature. Hot, loose connectors show up dramatically on these thermal pictures, especially in comparison to cooler, tight connections. This non-contact technique is perfect for checking energized components and scanning operational equipment, but it can't measure concealed (thermally-insulated) insulation or connections. Likewise, electrical panels must be open for the imager to measure the components. Follow NFPA 70E safety procedures and wear appropriate personal protective equipment (PPE) in these instances.

Connection/switch resistance. Another method for checking connectors is by electrically measuring the resistance of the connection. On an energized system, a resistive connection will cause a measurable voltage drop across the connection. A precise, properly-rated handheld voltmeter will do the job. However, this test does involve probing an energized system, so safety is a concern. The technician must closely follow PPE requirements and OSHA protocols.

On a de-energized system, using a micro-ohmmeter will produce much more accurate results. This tool applies a dc current of 10 amps or more through a connector and precisely measures the voltage drop. This test shows the resistance of a connection down to a fraction of a micro-ohm, insuring that the connection will not dissipate excessive heat—or, identifying connectors that could be hazardous.

Insulation testing. Insulation resistance is measured between phase conductors and between phase conductors and ground conductors. Good insulation should have very high resistance. An insulation tester applies a high dc voltage to de-energized, isolated components. The instrument then measures the resistance between the two points. This testing can be used to check large segments of insulation, including long lengths of cable, transformer windings, and motor windings. Low insulation resistance readings can indicate that somewhere on that length the cable is breaking down, potentially causing a short.

Ground resistance testing. Periodic ground measurements can help make sure lightning damage is minimized in the event of a strike. Obviously the need is more urgent if you are responsible for facilities in lightning-prone areas. A ground resistance test is usually performed during a system shutdown, because the ground electrode must be disconnected temporarily.

Transformer turns ratio. Insulation failure inside transformers can result in shorted turns, effectively reducing the number of turns on the effected side. A transformer with shorted turns is prone to overheating. You can check the ratio on a low voltage transformer by isolating the secondary from loads and using a voltmeter to compare the primary voltage to the secondary voltage. A more accurate approach is to use a special transformer-winding test set, which will give a precise ratio as well as a good picture of the magnetic characteristics.

Circuit Breaker Testing. Circuit breakers are the key to electrical fire prevention. Proper testing of circuit breakers requires special equipment and specialized expertise. Testing is performed with the breaker removed from the circuit and the tests verify the trip current and delay.

Power Quality Measurements. Power quality studies can uncover symptoms that signal potential overheating. Periodically measuring harmonic distortion will alert you to potential heating problems due to excessive harmonic current. Voltage sags can be viewed as annoyance, but in systems service a consistent load they may be caused by deteriorating connections. Many wiring problems become apparent during a comprehensive power quality study.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 7/2005 2519680 A-EN-N Rev A

The Basics of Predictive / Preventive Maintenance

Maintenance costs, as defined by normal plant accounting procedures, are normally a major portion of the total operating costs in most plants. Traditional maintenance costs (i.e. labor and material) in the U. S. have escalated at a tremendous rate over the past 10 years. In 1981, domestic plants spent more than $600 Billion to maintain their critical plant systems. By 1991, the costs had increased to more than $800 Billion and topped $1.2 Trillion in 2000. These evaluations indicate that between one third and one half of these maintenance dollars are wasted through ineffective maintenance management methods. American industry can no longer absorb this incredible level of inefficiency and hope to compete in the world market. Similar data for other countries is scarce, but we believe the situation is pretty much the same.

The dominant reason for this ineffective use of maintenance expenditures is the lack of factual data that quantifies when and what kind of maintenance is needed to maintain, repair or replace critical machinery, equipment and systems within a plant or facility. Typically, maintenance organizations do not track equipment performance, maintenance tasks performed, failure history or any of the other data that could, and should, be used to plan and schedule tasks that would prevent premature failures, extend the useful life of critical plant assets and reduce their life cycle cost. Instead, maintenance scheduling has been, and in many instances, still is determined by equipment failures or on the perceptions of maintenance personnel who arbitrarily determine the type and frequency of routine maintenance. For example, most facilities that employ thermographic inspections have it done once a year or every 6 months. This is a purely arbitrary decision, not support by any kind of factual data.

In addition, middle and corporate level management has ignored the impact of the maintenance operation on product quality, overall operating costs and more importantly on bottom-line profit. The general opinion has been "Maintenance is a necessary evil" or "Nothing can be done to improve maintenance costs". Perhaps these were true statements 10 or 20 years ago. However, the development of microprocessor or computer-based instrumentation and maintenance management systems provide the means to optimize maintenance effectiveness.

Microprocessor-based instrumentation, such as infrared monitoring and vibration devices, can be used to monitor the operating condition of critical plant equipment, machinery and systems. The knowledge gained from these instruments provides the means to effectively manage the maintenance operation. As a minimum, they provide the means to reduce or eliminate unnecessary repairs, prevent catastrophic machine failures, and reduce the negative impact of ineffective maintenance operation on the profitability of manufacturing and production plants. When their full capability is used, these instruments provide the means to optimize total plant performance, useful equipment life, and life cycle costs of the facility and its assets. Computer-based maintenance management systems provide the historical data

and means to use the data derived from predictive maintenance technologies, such as infrared monitoring and vibration.

Industrial and processing plants typically use two types of maintenance management, either run-to-failure or preventive maintenance.

Run-to-Failure Management

The logic of run-to-failure management is simple and straightforward. When a machine breaks down … fix it. This "If it ain't broke, don't fix it" method of maintaining plant machinery has been a major part of plant maintenance operations since the first manufacturing plant was built and on the surface sounds reasonable. A plant using run-to-failure management does not spend any money on maintenance until a machine or system fails to operate. Run-to-failure is a reactive management technique that waits for machine or equipment failure before any maintenance action is taken. It is in true a no-maintenance approach of management. It is also the most expensive method of maintenance management.

However, it should be said that few plants use a true run-to-failure management philosophy. In almost all instances, plants perform basic preventive tasks, i.e., lubrication, machine adjustments, and other adjustments, even in a run-to-failure environment. However in this type of management, machines and other plant equipment are not rebuilt nor are any major repairs made until the equipment fails to operate.

The major expenses associated with this type of maintenance management are:

- High spare parts inventory cost;
- High overtime labor costs;
- High machine downtime and
- Low production availability.

Since there is no attempt to anticipate maintenance requirements, a plant that uses true run-to-failure management must be able to react to all possible failures within the plant. This reactive method of management forces the maintenance department to maintain extensive spare parts inventories that include spare machines or at least all major components for all critical equipment in the plant. The alternative is to rely on equipment vendors that can provide immediate delivery of all required spare parts. Even if the latter is possible, premiums for expedited delivery substantially increase the costs of repair parts and downtime required to correct machine failures. To minimize the impact on production created by unexpected machine failures, maintenance personnel must also be able to react immediately to all machine failures.

The net result of this reactive type of maintenance management is higher maintenance cost and lower availability of process machinery. Analysis of maintenance costs indicate that a repair performed in the reactive or run-to-failure mode will average about three times higher than the same repair made within a scheduled or preventive mode. Scheduling the repair

provides the ability to minimize the repair time and associated labor costs. It also provides the means of reducing the negative impact of expedited shipments and lost production.

Preventive Maintenance

There are many definitions of preventive maintenance, but all these management programs are time-driven. In other words, maintenance tasks are based on elapsed time or hours of operation that are based on statistical or historical data for specific types of plant equipment. Figure 1.1 illustrates an example of the statistical life of a machine-train. The mean-time-to-failure (MTTF) or bathtub curve indicates that a new machine has a high probability of failure during the first few hours or weeks of operation, usually caused by manufacturing or installation problems. Following this initial period, the probability of failure is relatively low for an extended period of time. Following this normal machine life period, the probability of failure increases sharply with elapsed time or hours of operation. In preventive maintenance management, machine inspections, lubrication, repairs or rebuilds are scheduled based on the MTTF statistic.

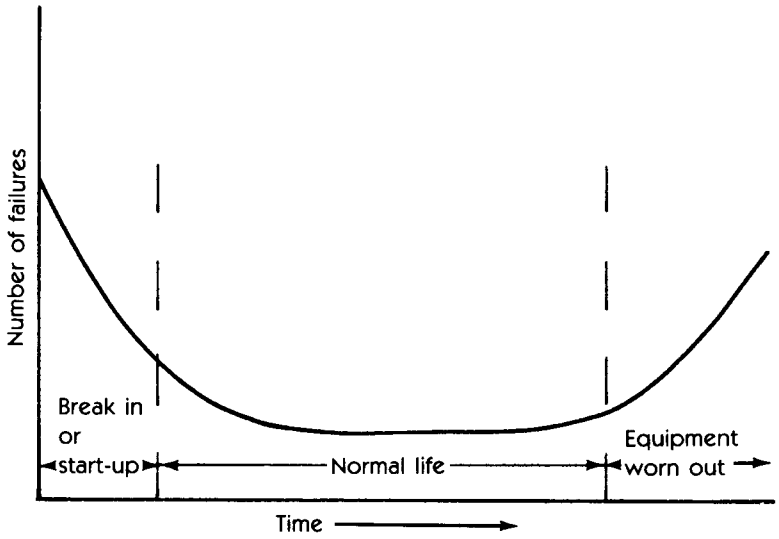


Figure 1. Bathtub curve.

The actual implementation of preventive maintenance varies greatly. Some programs are extremely limited and consist of lubrication and minor adjustments. More comprehensive preventive maintenance programs schedule repairs, lubrication, adjustments and machine rebuilds for all critical machinery in the plant. The common denominator for all of these preventive maintenance programs is the scheduling guideline. All preventive maintenance management programs assume that machines will degrade within the statistical time frame typical for its particular classification. For example, a single-stage, horizontal split-case centrifugal pump will normally run 18 months before its wear parts should be replaced. Using preventive management techniques, the pump would be removed from service and rebuilt after 17 months of operation.

The problem with this approach is that the mode of operation and system or plant specific variables directly affect the normal operating life of machinery. The mean-time-between-failures (MTBF) will not be the same for a pump that is handling water and one handling abrasive slurries. The normal result of using MTBF statistics to schedule maintenance is either unnecessary repairs or catastrophic failure. In the example, the pump may not need to be rebuilt after 17 months. Therefore the labor and material used to make the repair was wasted. The second option using preventive maintenance is even more costly. If the pump fails before 17 months, we are forced to repair using run-to-failure techniques. Analysis of maintenance costs have shown that a repair made in a reactive, i.e. after failure, mode will normally be three times greater than the same repair made on a scheduled basis.

Predictive Maintenance

Predictive maintenance is a condition-driven preventive maintenance program. Instead of relying on industrial or in-plant average-life statistics, i.e. mean-time-to-failure, to schedule maintenance activities, predictive maintenance uses direct monitoring of the operating condition, efficiency, heat distribution and other indicators to determine the actual mean-time-to-failure or loss of efficiency that would be detrimental to plant operations for all critical systems in the plant or facility. At best, traditional time-driven methods provide a guideline to *normal* machine-train life spans. The final decision, in preventive or run-to-failure programs, on repair or rebuild schedules must be made on the bases of intuition and the personal experience of the maintenance manager.

The addition of a comprehensive predictive maintenance program can and will provide factual data on the actual operating condition of critical assets, including their efficiency, as well as the actual mechanical condition of each machine-train and the operating efficiency of each process system. Instead of relying on industrial or in-plant average-life statistics, i.e. mean-time-to-failure, to schedule maintenance activities, predictive maintenance uses direct monitoring of the mechanical condition, system efficiency and other indicators to determine the actual mean-time-to-failure or loss of efficiency for each machine-train and system in the plant. This data provides maintenance management the factual data needed for effective planning and scheduling maintenance activities.

Predictive maintenance is much more. It is the means of improving productivity, product quality and overall effectiveness of our manufacturing and production plants. Predictive maintenance is not vibration monitoring or thermal imaging or lubricating oil analysis or any of the other nondestructive testing techniques that are being marketed as predictive maintenance tools. Rather, it is a philosophy or attitude that simply stated uses the actual operating condition of plant equipment and systems to optimize total plant operation. A comprehensive predictive maintenance management program utilizes a combination of the most cost-effective tools, i.e. thermal imaging, vibration monitoring, , tribology, and other nondestructive testing methods, to obtain the actual operating condition of critical plant systems and based on this factual data schedules all maintenance activities on an *as-needed* basis.

Including predictive maintenance in a comprehensive maintenance management program will provide the ability to optimize the availability of process machinery and greatly reduce

the cost of maintenance. It will also provide the means to improve product quality, productivity and profitability.

A predictive maintenance program can minimize unscheduled breakdowns of all electrical and mechanical equipment in the plant and ensure that repaired equipment is in acceptable condition. The program can also identify problems before they become serious. Most problems can be minimized if they are detected and repaired early. Normal mechanical failure modes degrade at a speed directly proportional to their severity. If the problem is detected early, major repairs can be prevented, in most instances.

Benefits

Effective use of preventive maintenance, including predictive technologies, will eliminate much of the 33% to 50% of maintenance expenditures that are wasted by most manufacturing and production plants. Based on historical data in the USA, the initial savings generated by effective preventive/predictive maintenance programs fall into the following areas:

1. Elimination of unscheduled downtime caused by equipment or system failures. Typically, reductions of 40% to 60% are achieved within the first two years and up to 90% reductions have been achieved and sustained within five years.

2. Increased manpower utilization. Statistically, the average "wrench-time" of a maintenance craftsperson is 24.5% or about 2 hours per shift. By identifying the precise repair task needed to correct deficiencies within a plant asset, as well as the parts, tools and support needed to rectify the problem, preventive/predictive maintenance can dramatically increase effective "wrench-time". Most plants have been able to achieve and sustain 75% to 85% effective utilization.
3. Increased capacity. The primary benefit of effective preventive/predictive maintenance programs is an increase in the throughput or production capacity of the plant. Short-term, i.e. 1-to-3 years, increases in sustainable capacity have ranged between 15% and 40%. Long-term improvements of 75% to 80% have been achieved.
4. Reduction of maintenance expenditures. In some cases, actual maintenance expenditures will increase during the first year following implementation of an effective preventive/predictive program. This increase, typically 10% to 15%, is caused by the inherent reliability problems discovered by the use of predictive technologies. When these problems are eliminated, the typical result is a reduction in labor and material cost of between 35% and 60%.
5. Increased useful life. Typically, the useful operating life of plant assets will be extended by 33% to 60%. Detecting incipient problems or deviations from optimum operating conditions before damage to equipment occurs derives this benefit. Making minor adjustments or repairs and not permitting a minor deficiency from becoming a serious problem can extend the effective useful life extended almost indefinitely.

Summary

Artificially high maintenance costs caused by a combination of ineffective management methods and the lack of timely, factual knowledge of asset condition represent a substantial opportunity for almost every manufacturing and production facility worldwide. Effective use of the preventive/predictive technologies provides the means to take advantage of this opportunity. Used correctly, the 33% to 50% of wasted maintenance expenditures can be eliminated and effective use of plant resources, both production and maintenance can be achieved and sustained.

FLUKE®

Thermal predictive maintenance at a coal plant

Application Note

Testing Functions **Case Study**

Measuring tools: Fluke Ti30 Thermal Imager

Operator: Coal plant/ power generation

Tests conducted: Power distribution, switchyard, motors, boilers, pipes, traps and valves

As monopolies, electric utilities are charged with providing the highest quality product to the public at the lowest possible cost. Simultaneously, as publicly-owned companies, they also need to generate a return on investment for their shareholders. They have a fiduciary responsibility to operate efficiently, and predictive maintenance is an essential component in fulfilling this responsibility.

While many people in the power generation industry are familiar with annual infrared thermography surveys as part of PdM, the coal plant in this case study uses a thermal imager year round. There are two differences in their approach.

1. They use a mid-range thermal imager with enough pixel count, accuracy, and temperature range for their applications.
2. They use it to troubleshoot problems, track critical equipment more closely, and follow up repairs after the annual survey.

Power distribution

Delivering consistent, reliable electricity is a power generator's highest priority. For this reason, the primary use of infrared thermography at this plant is regular monitoring of power distribution equipment. For example, 2300 V and 4160 V breakers and transformers should be inspected with a thermal imager to identify problems prior to scheduled maintenance outages.

Switchyard

Switchyard inspections are normally performed during the pre-dawn hours in order to avoid solar reflections and effects from wind. During pre-dawn, the load is lighter but the air is usually calm, so any problems that are observed are certain to be significant, as they will be much hotter during the period of peak load. Traditionally, these inspections would be performed during periods of maximum load, however local conditions at that time of day can mask serious problems.

Boilers, pipes, traps and valves

While delivery of electricity is essential, efficient production is equally important. At this coal plant, for example, steam is produced from coal fired boilers and electricity is produced from steam driven turbines. When steam valves leak or fail, high energy content steam or water blows through to the condenser. This represents significant money down the drain. The thermal imager allows maintenance staff to regularly scan the pipes, valves, and traps, identifying these problems early on and controlling the operational cost of electricity production.

Energy losses are not limited to the steam lines. Infrared thermography is used to inspect the boilers to identify areas of insulation breakdown. Hot areas on the boiler walls indicate areas of worn insulation and significant energy losses. Infrared thermography helps identify these areas so they can be repaired during the next maintenance outage.

Motors

At most plants with in-house imagers, nearly all of the infrared analysis is qualitative and comparative—examining similar pieces of equipment under similar load. A primary example is the inspection of pulverizer motors. The steam boilers are hungry for coal. Twenty-seven 400 to 500 horsepower motors drive the pulverizers which feed the boilers.

In advanced PdM systems, each aspect of the system may have its own monitoring program. For example, this coal plant should have a motor casing monitoring program, where the case temperature for each motor is regularly examined. Motors all have NEMA temperature ratings on their nameplates, providing the usual operating temperatures as a baseline. The normal apparent temperature is approximately 120 – 140 °F, depending on ambient conditions. As the temperature rise approaches 40 degrees, it usually indicates the need to clean the filters. When the temperature rise exceeds 40 degrees, it indicates that the motor needs to be scheduled for cleaning and reconditioning. Since the motors are all about the same size and operating under similar loads, it's a fairly simple matter to identify "hot" motors comparatively and take corrective actions.

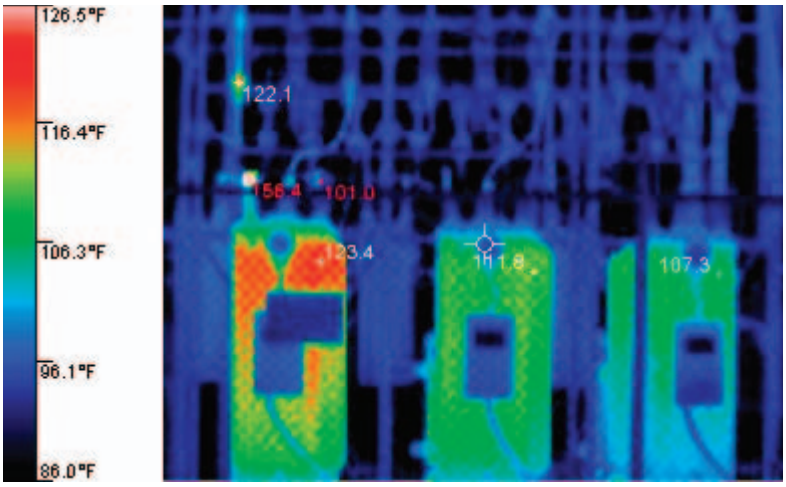
Prioritizing problems

Infrared thermography helps identify maintenance needs but prioritizing the problems requires thoughtful evaluation of many factors. The most significant problem is not necessarily the one with the hottest apparent temperature. Other factors include criticality of the equipment, total repair/replacement cost, safety concerns, and lost production costs.

Basic vs. advanced thermography

Much of the equipment in coal-fired power generating stations can be efficiently inspected using comparative infrared analysis. In this case, the plant continued to hire out the annual survey, so that it had professional thermal images of all critical equipment to compare their own images to during the year.

For example, most of the metal surfaces in a coal-fired plant are heavily oxidized and coated with fly ash. This means that most of the surfaces of interest generally have an emissivity of about 0.95. Since that's the default emissivity setting on most thermal imagers, those surfaces yield accurate thermal images year round.



This thermal imgae shows hot secondary connections on the transformer.

Examine transformers, comparing similar connections under similar loads.

However, if the metal surface of a motor casing is shiny, it looks like a mirror in the infrared region. Instead of seeing the temperature of the motor, the infrared camera "sees" a combination of some of the heat of the motor and some of the heat of objects around the motor. To compensate, thermographers paint a black spot on the surface or use a contact temperature probe to allow them to adjust the emissivity until the infrared reading matches the contact probe.

While issues like emissivity are minimized by dirty metal surfaces, other issues like reflections, convective losses due to wind, and other conditions can lead to erroneous conclusions.

More advanced infrared thermography involves learning the principles of heat transfer, reflectance (mirrors), emittance (walls) and transmission (windows). Special settings for each piece of equipment can also be obtained from the annual consulting thermographers.

Predictive maintenance basics

Predictive maintenance is especially important to power-generation facilities because so many are running past their original design lives. Preventing unplanned downtime while operating aging equipment on a fixed budget doesn't leave too many options.

Predictive maintenance (PdM) involves monitoring equipment over time for conditions that indicate impending failure, determining whether corrective action is required, and, if necessary, taking that action before the equipment fails. The goal is to avoid unplanned downtime and schedule repairs.

PdM technicians identify critical production assets, determine how often they need to be monitored, set up an inspection route and schedule, and regularly measure key indicators. Then, they compare those measurements over time, looking for changes in operating conditions that indicate potential breakdowns. Available monitoring and measuring methods include infrared (IR) temperature measurement, vibration analysis, oil analysis, ultrasonic testing, electrical measurement, power quality, insulation resistance, and thermal imaging.

The benefits include significantly reduced downtime, maximized uptime, stocking an optimum number of spare parts, and lower labor costs for maintenance. Overall, PdM programs increase capacity or productivity using existing equipment. Some power generation facilities find that the data collected for predictive maintenance is also useful for meeting environmental documentation requirements.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2519659 A-EN-N Rev A

FLUKE®

Thermography and motor-condition monitoring at a paper mill

Application Note

Testing Functions **Case Study**

Measuring tools: Fluke Ti30 Thermal Imager

Operator: Bill Gray, paper mill plant maintenance reliability specialist

Equipment inspected: Motors, pumps, heat exchangers, gear boxes, bearings, MCCs

Until three years ago, the only thermography performed at the specialty paper mill featured in this case study was done by a consulting firm that inspected the switchgear once a year. The inspectors usually found hotspots that needed to be eliminated, but after plant technicians performed a fix, it would have been cost prohibitive to call the consultants back to verify that each repair was successful. That was a problem.

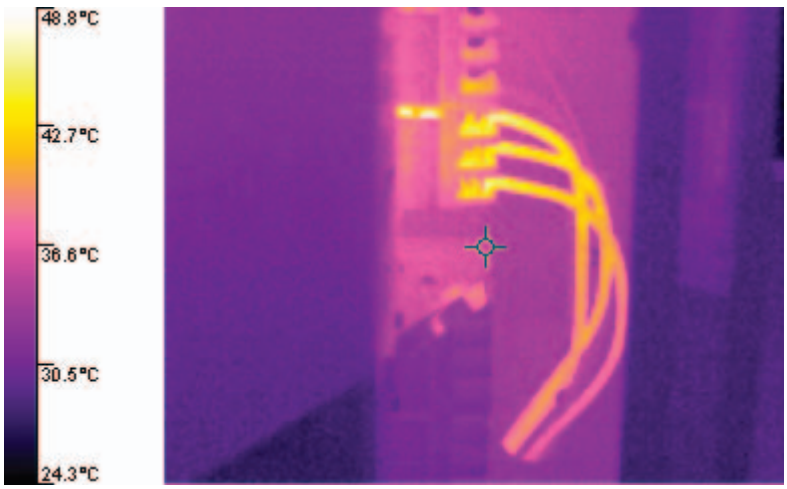
The mill runs 24x7, and they can't afford unscheduled shutdowns. In particular, they wanted to be able to inspect switchgear more than once a year, to monitor other equipment before and after repairs, and establish baselines on new equipment. Then, the facility purchased a Fluke Ti30 Thermal Imager.

Bill Gray, the plant's maintenance reliability specialist, trained in its use and became a Level I Thermographer. Gray began conducting thermal inspections of equipment as needed. Now, having used the thermal imager for two years, he's using the experience he's gained to develop a formal motor-condition monitoring reliability maintenance program.

Post-repair and other applications

The paper mill still contracts with outside thermographers to monitor the switchgear once a year, because of the time it takes to do a complete survey. The contractor surveys about 5,000 pieces of equipment over a week.

However, when Gray started taking thermal images of the repairs performed as a result of those outside thermographers' findings, he discovered that about 30 percent of the repairs were either unsuccessful or had made things worse. There had been a significant disconnect between the outside thermographers and the facility's interpretation of what repairs were



Hot connections.

needed. Now Gray and his crew can work on the problem until the repair is satisfactory.

Since infrared imagers can monitor undesirable thermal buildup in an array of critical process systems, Gray also uses the Ti30 to detect dysfunctional pumps, under-performing heat exchangers, and a host of other equipment including gearboxes, bearings and motors.

Motor monitoring

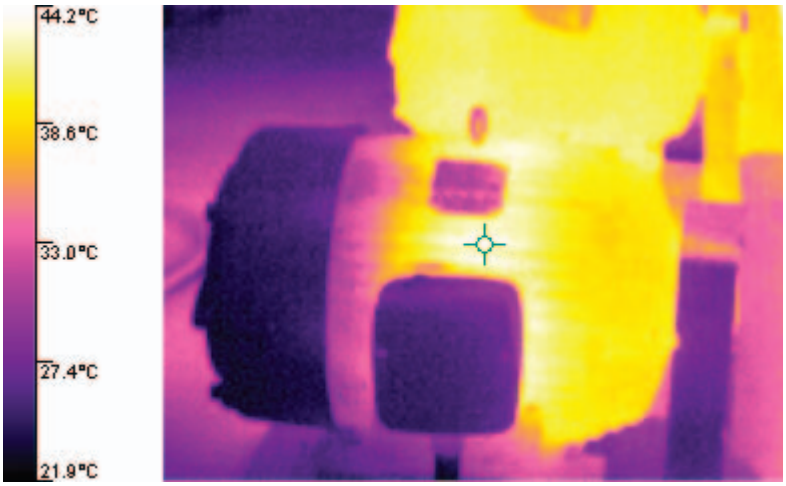
The mill is still in the process of developing its own thermal inspection routes. So, they started out by using thermal images on an "exceptional occurrence" basis.

In other words, if someone walks past a motor and notices it's hot, then Gray take a thermal image to find out where and why the motor is hot. If vibration data indicates a bad bearing or imbalance, he can confirm those findings with the camera by finding out if the motor is hot and where it's hot. A motor's heat signature tells them a lot about its quality and condition. In particular, every increase of 10 °C on a motor's windings above its design operating temperature cuts the life of its windings' insulation by 50 percent, even if the overheating is only temporary.

The mill has approximately 3,000 motors ranging from fractional horsepower units on pumps that supply coating and additives to 1,000-horsepower units powering large operations. If even that little pump motor fails, a whole batch of paper can be ruined or the machine shut down.

So far, Gray keeps thermographic records of motors that have needed repair. That way, he can go back and check them later to make sure the corrective action was successful. In one case, he had a big motor that was running warm. It was on a fan pump on the paper machine that supplied the stock to the head box. Nobody knew exactly how warm the motor was running, but everyone knew that if that pump went down the machine would be dead in the water.

Gray took thermal images of the motor. At the hottest spot on the housing, the image showed



Hot casing on a motor for the cream separator.

284 °F. The image also showed that the heat was coming from the windings.

He filed a report and then monitored the motor closely for about a week until it the maintenance team could install a new motor and send the other one out for repairs. The replacement was deemed so necessary that they shut the machine down for the transfer, rather than waiting for a scheduled shutdown and risking a failure with no replacement.

Moving toward a formal motor-monitoring program

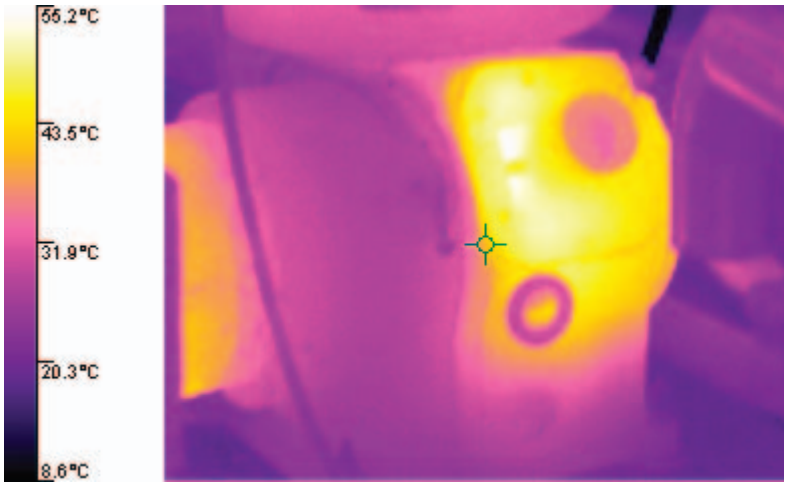
As part of the formal motor-monitoring, Gray will concentrate on shafts, couplings, gearboxes and other mechanical components. Once the inspection routes and schedules are finalized, he hopes to get the maximum life out of his expensive, high-horsepower motors.

He'll be combining data from visual inspections, infrared spot thermometer checks, vibration analysis, thermography and current-phase analysis into a new condition-based monitoring and asset management system. The system ties the collected data to the specific piece of equipment and flags anything that is not within predetermined parameters.

In the future, when Gray uses thermography on a motor, he'll be able to tie the images or a report to the overall system data for that piece of equipment, and to a work order for use by technicians making the repairs.

By putting all the analysis data together into one picture, he'll be able to deal most effectively with problem motors and prolong the lives of critical ones.

Hot connections on the Motor Control Center.



The gearbox of the separator motor, showing extreme (white) hotspots.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2519626 A-EN-N Rev A

FLUKE®

- Complete imaging solution
- Lowest cost of ownership
- Designed for predictive maintenance

Fluke Ti30™ Thermal Imager

Everything needed for everyday imaging.

Lowest ownership cost for a fully radiometric imager

The Fluke Ti30 Thermal Imager provides the lowest total ownership cost for a full-featured, radiometric imager. The package includes all the hardware, software and training required without any additional costs. Standard calibration and service rates for the Ti30 imager are also extremely competitive for the industry.

- Docking Station with Universal Power Adapter and USB Connection
- Hardshell Carrying Case
- USB Field Cable
- Rechargeable Battery Pack
- AA Battery Pack (batteries not included)
- Interactive CD with InsideIR Software and User Manual
- Training Presentation CD
- Carrying Pouch
- Wrist Strap
- Quick Reference Card
- One Seat in Professional Training Course

To understand your full investment in a thermography program, here are some questions to consider:

Product and performance
- Is the camera you are purchasing fully radiometric (i.e. measures temperature on every one of the available pixels)?
  - The ability to measure absolute temperature is critically important to establishing an effective predictive maintenance program for electrical and mechanical equipment.

Software
- Is there an additional cost for professional reporting software?
- Is there a licensing fee for each additional user or desktop?

Training and ease of use
- Is training offered at no additional cost?
- Is the camera easy to use?
- Will your electricians and/or mechanics, with only some basic training, be able to use the camera as a tool to help them do their job better?

Re-calibration, service and repair
- How much does it cost to send the camera in for calibration?
- How much do basic repairs cost?
- How likely is it that the lens will be scratched?

Additional batteries, chargers or replacements
- How does the battery recharging time compare to the battery discharging time?
- How many batteries and charging stations are needed to get through a full day of inspections?

Fluke Ti30 Thermal Imager

Unbeatable solution for infrared predictive maintenance.

Inspection routes improve maintenance performance.

Both preventive and predictive maintenance programs rely on periodic inspections of critical plant assets. To optimize a program's success, maintenance personnel develop inspection routes by determining the frequency, sequence and physical course for equipment needing inspection.

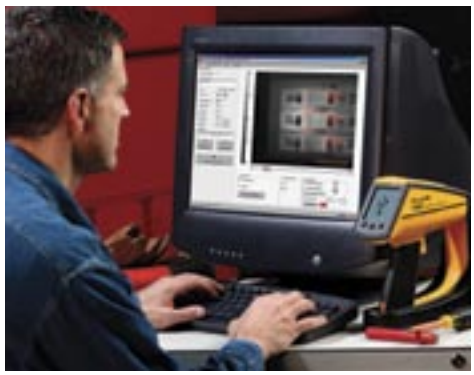
The Fluke Ti30 Thermal Imager uniquely supports thermography inspection routing. After the first inspection, the images taken can be combined in the InsideIR™ software with location names and temperature data, and uploaded to the imager for use as a routing guide.

During subsequent inspections, an on-camera display prompts the user exactly where to take images—improving accuracy. The new images are easily compared to previous scans, helping to identify potential problems before they cause failure.

Expand your predictive maintenance program.

The Fluke Ti30 Thermal Imager enables plant thermography specialists to manage a much larger infrared predictive maintenance program—and delegate inspection routing responsibilities to appropriate personnel, such as electricians and mechanics, who specialize in the equipment being inspected. This frees the trained expert to handle program management, image analysis and interpretation, and report generation.

Obtain high-quality thermal images with a simple "click" of the trigger.



Download images and data into the companion InsideIR software for analysis and reporting.

Assign a unique name, preset emissivity and RTC values, assign alarm limits and add meaningful comments to each measurement location.

Inspections can now be delegated to electricians and mechanics, those most familiar with the equipment. They simply follow the on-camera, step by step routing instructions, point, focus and shoot.

Easy to learn and easy to use.

- Single-level menus make set-up easy, without the complicated multi-layer decisions other imagers require.
- Gain and level controls can be set to "automatic" or changed manually for maximum flexibility.
- Squeeze trigger once to freeze an image—then choose whether to store it or discard without saving.
- Direct access switches for laser, temperature scale, palette, backlight and measurement modes means changing takes only a second.

Designed for the industrial maintenance environment.

The Ti30 thermal imager enables infrared inspections all day—every day. The camera's 5+ hour battery life, and 100-image storage capacity, are more than enough for an entire shift of uninterrupted inspections. Other systems would require three batteries, multiple chargers, and/or additional memory devices for similar performance.

With the rugged Ti30 thermal imager, maintenance organizations can conduct thermographic inspections anytime, anywhere, and identify potential equipment problems before they cause failure. Use the Ti30 imager regularly—not just in a crisis or for an annual maintenance check.

Best complete thermog

Versatile solution for plant maintenance professionals.

- High performance features for the expert, packaged in an easy to use device for beginners.
- Adjust key image parameters (emissivity, RTC, temperature level and gain) in the field on the camera, or back at the office on the PC.
- Large, clear LCD display works well both indoors and outside.
- Use the docking station for USB communications in the office, or the USB field cable when working remotely.
- Use the rechargeable battery pack or the standard AA pack.

FLUKE®

InsideIR software: Powerful and flexible.

The Fluke Ti30 Thermal Imager allows maintenance personnel to quickly and easily capture high-quality infrared images. Because the camera collects 12 bits of information for every one of its 19,200 pixels, users in the field can simply point, focus and shoot. With a properly composed, well-focused image, all further analysis can be performed with the InsideIR software in the quiet, comfort and safety of an office.

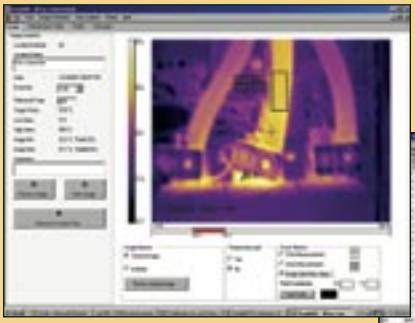
In the imager during the scan, or later in the InsideIR software, adjust:
- Palette settings
- Emissivity
- Reflected temperature correction values
- Level and gain

This approach provides flexibility and eliminates the need to re-scan equipment if different settings are desired once the user is back in the office. The file of images and data can also be e-mailed to other Ti30 imager-InsideIR software users, making information sharing and cross-checking easy.

Includes professional thermography training course to accelerate return on investment.

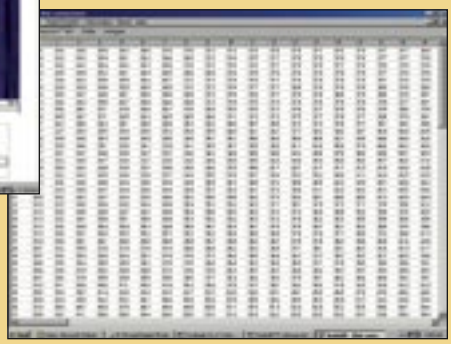
- Practical, hands-on course designed to shorten the learning curve for new Fluke Ti30 Thermal Imager owners covers:
  - Infrared and thermography theory
  - Primary applications for electrical and mechanical systems
- Taught by certified thermography professionals.

graphy solution



Capture clear thermal images and easily analyze the radiometric (temperature) data for all 19,200 pixels.

Analyze individual images, easily identify hot (or cold) spots and select areas for min., max. and avg. temperature values.



Quickly and easily create professional reports using InsideIR software.

Fluke Ti30 Thermal Imager Specifications

Detector	
Detector Type:	120 x 160 uncooled focal plane array
NETD (Thermal Sensitivity):	200 mK
Thermal	
Temperature Range:	-10° to 250 °C (14° to 482 °F)
Accuracy:	±2 % or ±2 °C (±3 % or 3 °C from -10 to 0 °C)
Optical	
Optical Resolution:	90:1
Slit Response Optical Resolution:	225:1
Minimum Diameter Measurement Spot:	7 mm (0.27") at 61 cm (24")
Field of View (FOV):	17° Horizontal x 12.8° Vertical
Target Sighting:	Single laser (Meets IEC Class 2 & FDA Class II requirements)
Controls and Adjustments	
Focus:	Focusable, 61cm (24") to infinity
Temperature Scale:	°C or °F selectable
Palettes:	Gray, Ironbow or Rainbow
Measurement Modes:	Automatic, Semi-Automatic, or Manual
LCD Backlight:	Bright, Dim, Off-Selectable
Adjustable Emissivity:	0.10 to 1.00 by 0.01
Reflected Background Temperature:	-50 to 460 °C (-58 to 860 °F)
Environmental	
Ambient Operating Temperature:	-10 to 50 °C (14 to 122 °F)
Relative Humidity:	10 to 90 % Non-Condensing
Storage Temperature:	-25 to 70 °C (-13 to158 °F) [without batteries]
Other	
Storage Capacity:	100 images
Power:	Rechargeable battery pack or 6 AAs (not included)
Battery Life:	Minimum 5 hours continuous use
Image Frame Rate:	20 Hz
Thermal Analysis Software:	InsideIR (included)
PC Software Operating Systems:	Microsoft® Windows® 98®, 2000® or XP®
Weight (includes batteries):	1 kg (2.2 lb)
Warranty:	1 year (U.S. only)

Ordering information

The Fluke Ti30 Thermal Imager is sold exclusively through authorized thermography distributors. To request a demonstration or order a Ti30 imager, visit **www.fluke.com/thermography** or call (800) 866-5478.

The Fluke Ti30 Thermal Imager, formerly the Raytek ThermoView™ Ti30 Thermal Imager, is now part of the Fluke line of test and measurement equipment.

Fluke. *Keeping your world up and running.*

Fluke Thermography
PO Box 1820, Santa Cruz, CA USA 95061-1820

Fluke Thermography Europe
Blankenburger Straße 135
D-13127 Berlin
Germany

For more information call:

In the U.S.A. (800) 866-5478 or
Fax (831) 425-4561 or
Ti30support@fluke.com

In Europe/M-East/Africa +49 30 478 00 80 or
Fax +49 30 471 02 51 or
Ti30support.de@fluke.com or
International (831) 458-1110 or
Fax (831) 458-1239 or
Ti30support@fluke.com
Web access:
http://www.fluke.com/thermography

©2005 Fluke Corporation. All rights reserved.
Specifications subject to change without notice.
Printed in U.S.A. 1/2005 2418199 B-US-N Rev B

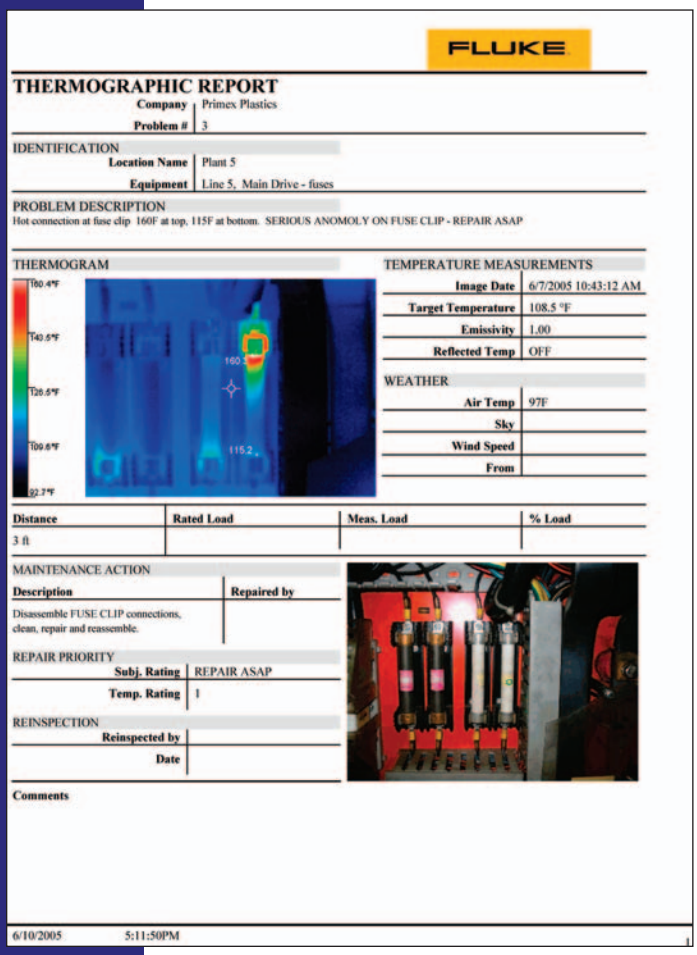
FLUKE®

How to document thermal findings:

Creating successful reports

Application Note

In any industry, optimizing uptime is essential for increasing productivity and competitiveness. How? Secure the reliability of key production assets and prevent failures through predictive maintenance (PdM). Typical PdM programs advocate periodic inspections of critical assets and trending those measurement results to spot imminent breakdowns.



FLUKE

THERMOGRAPHIC REPORT

Company: Primex Plastics
Problem #: 3

IDENTIFICATION
Location Name: Plant 5
Equipment: Line 5, Main Drive - fuses

PROBLEM DESCRIPTION
Hot connection at fuse clip 160F at top, 115F at bottom. SERIOUS ANOMOLY ON FUSE CLIP - REPAIR ASAP

THERMOGRAM

TEMPERATURE MEASUREMENTS

Image Date	6/7/2005 10:43:12 AM
Target Temperature	108.5 °F
Emissivity	1.00
Reflected Temp	OFF

WEATHER

Air Temp	97F
Sky	
Wind Speed	
From	

Distance	Rated Load	Meas. Load	% Load
3 ft			

MAINTENANCE ACTION

Description	Repaired by
Disassemble FUSE CLIP connections, clean, repair and reassemble.	

REPAIR PRIORITY
Subj. Rating: REPAIR ASAP
Temp. Rating: 1

REINSPECTION
Reinspected by:
Date:

Comments

6/10/2005 5:11:50PM

Since increases in temperature are associated with nearly all mechanical and electrical failures, thermal imaging has broad application in PdM programs. A thermal imager uses infrared technology to capture two-dimensional images that reveal the temperature profiles of objects.

Capturing a thermal image using the latest handheld instruments takes very little time. But what does one do with thermal images after capturing them?

At a minimum, the technician operating a thermal imager should store collected images for comparative reference during the next inspection. He or she should also note key temperature points within the target and track those.

However, when an image reveals a situation that may require repairs, a report should be created describing what the image shows and possibly suggesting a remedy. The report can then be circulated to personnel responsible for equipment reliability, who can investigate the problem further.

The following discussion describes how to set up a thermal imaging process that leads to truly useful reports.

For more information on Fluke Predictive Maintenance Products and Services go to **www.fluke.com/thermography**

FLUKE®

Preparing for reporting—route planning

First, key operations, maintenance and safety personnel identify which equipment qualifies as critical. A critical asset is one that, if it fails, creates a safety or health hazard, endangers property or adversely affects productivity or the product. Then, those units are grouped together into one or several inspection routes, using the software that accompanies the thermal imager. A route description includes the location of each stop and the images to be collected there. This information is then loaded into the thermal imager, to guide the image collector (technician) on the route.

Preparing for reporting—reminder notes

Supervisors should also use their thermal software to create route-specific reminder notes. Typically, these reminder notes include:

- **"Safety First"** information: general safety guidelines, as well as specific *dos* and *don'ts* for each stop.
- Specific instructions on where to stand and what to view at each stop, to ensure consistency from trip to trip
- "How to" information about using the thermal imager, especially for beginning thermographers
- Information about special conditions at specific stops, such as high background heat, the possibility of heat-dissipating winds, etc.

What has all of this to do with reporting? In any PdM program, it is essential to track and compare equipment condition from one thermal reading to the next. Readings as well as reports must present reliable images for comparison. Reminder notes help bring consistency to image collecting, and consistency in collecting images is the key to effective reporting.

Preparing for reporting—image collection

During route planning, the maintenance manager also needs to take initial thermal and digital images for each stop on the route. The thermal images serve both as baseline images for comparison and as examples of what to "capture" at each stop. Then, if an inspection route is well thought out and reminder notes are followed, the chances are good that a technician will secure good, usable thermal images. The corresponding digital photos make it much easier to interpret the thermal images.

What to report?

When a technician has completed the thermal inspection route, he or she returns to the maintenance department and loads the collected images into the computer or network used to create the route. The thermal software makes the transfer possible and helps maintenance personnel organize the results into reports.

The reason for a report is to produce action, such as the writing of a repair order or further monitoring. What typically gets reported, then, are anomalies—e.g., motors or bearings running hotter than others—or equipment apparent temperatures trending toward an alarm situation.

Reporting options

Using the thermal software, technicians can enhance the images for better viewing in the report, describe the image analysis, annotate spot measurements at specific locations in images, and incorporate any comments entered during the route.

Typically, a report includes both thermal and digital images. It also includes the date, time and equipment designation and, possibly, a problem number and a work order number. It might also include diagnostic comments, if the reporter is competent to make such judgments. (For a detailed listing of what a report might include, see Paragraph 7, "Report," of the latest edition of ASTM Standard E 1934, *Standard Guide for Examining Electrical and Mechanical Equipment with Infrared Thermography*.) Reports created with the software accompanying Fluke handheld imagers may be saved as Microsoft® Word documents and PDFs. This capability allows a reporter to either print out hard copies or attach them to e-mails for distribution to the appropriate personnel for action.

Fluke. *Keeping your world up and running.*

An imaging tip:

Many thermographers find their reports get lost in the great shuffle of papers that seems to accompany maintenance programs in most plants. One trick is to print a "hi-lighter" yellow boarder on the report. You'll be amazed at how quickly it gets action! Another is to create a bulletin board where thermal image color print outs and reports can be posted. This helps communicate the importance of predictive maintenance as well as the value of thermal imaging.

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 7/2005 2519615 A-EN-N Rev A

FLUKE®

Monitoring transformers

Application Note

Most transformers are cooled by either oil or air while operating at temperatures much higher than ambient. In fact, operating temperatures of 65 °C for oil-filled units and 150 °C for air-cooled transformers are common. Nevertheless, problems with transformers often manifest themselves in overheating or hot spots, making thermal imaging a good tool for finding problems.

Power and distribution transformers change electric current from one voltage to another. They accomplish this process when electricity flowing through a coil at one voltage induces current in a second coil. The amount of change is a function of the number of windings on the coils.

The following discussion focuses on monitoring external and internal conditions of oil-filled transformers. Dry transformers also can exhibit both external or internal connection problems, and external connection problems can be detected as with oil-filled units. Beyond that, dry transformers have coil temperatures so much higher than ambient, it is difficult to detect internal problems before irreparable damage occurs. Other diagnostic technologies, including built-in temperature and pressure gauges, may be more reliable for assessing the internal conditions in dry transformers.

The procedures described here should be conducted in conjunction with the recommendations of NFPA Standard 70B, *Recommended Practice for Electrical Equipment Maintenance, Chapter 9: "Power and Distribution Transformers."*

What to check?

At a minimum, use your thermal imager to look at external connections, cooling tubes and cooling fans and pumps as well as the surfaces of critical transformers.

What to look for?

In oil-filled transformers, monitor the following external components:

- **High- and low-voltage bushing connections.** Overheating in a connection indicates high resistance and that the connection is loose or dirty. Also, compare phases, looking for unbalance and overloading.
- **Cooling tubes.** On oil-cooled transformers, cooling tubes will normally appear warm. If one or more tubes are comparatively cool, oil flow is being restricted and the root cause of the problem needs to be determined.

At 94 °F, one of the terminals on this 1320 V – 480 V main tranformer is running about 20 °F hotter than it should.

- **Cooling fans/pumps.** Inspect fans and pumps while they are running. A normally operating fan or pump will be warm. A fan or pump with failing bearings will be hot. A fan or pump that is not functioning at all will be cold.

Problems with surge protection and lightning arrestors leaking to ground and current tracking over insulators can also be detected using thermography. However, finding such problems requires the capture of subtle temperature differences often under difficult-to-monitor conditions. Ultrasound or some other technology might be a more reliable monitoring technique for these problems.

For thermography to be effective in pinpointing an internal transformer problem, the malfunction must generate enough heat to be detectable on the outside. Oil-filled transformers may experience internal problems with the following:

- **Internal bushing connections.** Note: connections will be much hotter than surface temperatures read by an imager indicate.
- **Tap changers.** Tap changers are devices for regulating transformer output voltage to required levels. An external tap changer compartment should be no warmer than the body of the transformer. Since not all taps will be connected at the time of an inspection, IR inspection results may not be conclusive.

A good approach is to create regular inspection routes that include the transformers on all essential electrical circuits. Save thermal images of each one on the computer and track temperature measurements over time, using the software that comes with the IR camera. That way, you'll have baseline images with which to compare later images that will also help you determine if temperature levels are unusual and, following corrective action, determine if maintenance was successful.

What represents a "red alert?"

Equipment conditions that pose a safety risk should get the highest priority for repairs. However, the imminent failure of any piece of critical equipment constitutes a red alert. Key operations, maintenance and safety personnel should play roles in quantifying "warning" and "alarm" levels for the power supplies to critical assets. (Note: alarm levels for specific equipment can be set on Fluke handheld thermal imagers.) Throughout, personnel responsible for monitoring transformers should keep in mind that like an electric motor, a transformer has a minimum operating temperature that represents the maximum allowable rise in temperature above ambient, where the specified ambient is typically 40 °C. It is generally accepted that a 10 °C rise above its maximum rated operating temperature will reduce a transformer's life by 50 percent.

What's the potential cost of failure?

For power delivery companies, transformer failures can be very costly. A transformer failure in the summer of 2005 in Oslo, Norway resulted in a 50-minute power outage for 200,000 customers, left people trapped in subways and elevators, and cost the power delivery company responsible for the transformer 10 million Norwegian kroner (≈ $1.6 million, US) in compensation to NVE, Norway's main power supplier.[2]

For a failed transformer at your facility, you can do an analysis of the cost of repair or replacement, lost production opportunity and lost labor costs for affected equipment.

Follow-up actions

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report, including a thermal image and a digital photograph of the equipment. That's the best way to communicate problems you find and to suggest repairs.

Perceived internal problems in oil-cooled transformers can often be verified by a gas-in-oil analysis. The presence of methane in the oil indicates overheating. Acetylene indicates arcing. This test can also be used to help trend the severity of a problem in a transformer that simply cannot be taken down for repairs. **Warning:** Never draw liquid samples from an energized transformer except via an external sampling valve. Also, regular gauge and load monitoring and visual inspections for leaks, corrosion, et cetera will help guide further maintenance activities. In any event, follow the guidance of NFPA 70B, Chapter 9.

[1]Background information supplied by John Snell & Associates.
[2]Source: www.aftenposten.no/english

Imaging tip

Winds (or air currents inside) in excess of even a few miles per hour will reduce the surface temperatures of transformers and other equipment, causing real problems to seem less significant or even making them undetectable by your thermal imager. Inside plants, air currents are often 10 to 15 miles per hour. Buy a high-quality wind meter and use it. When you must inspect in high convection situations, note all problems for a follow-up inspection. Even small temperature increases may become critically hot when airflow is reduced.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2531346 A-EN-N Rev A

FLUKE®

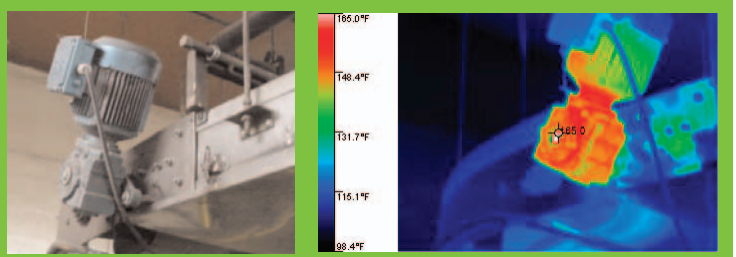
Industrial gearboxes

Application Note

Many industrial machines use gearboxes to alter and/or vary the standard speeds of electric motors. The lifeblood of any gearbox is the oil within it that lubricates the gears. If the oil level in a gearbox gets too low or loses its ability to lubricate, the gearbox will eventually fail, preceded by overheating. That's where thermal imaging comes in.

Traditionally, preventive maintenance for gearboxes has consisted of regularly checking their oil levels and replenishing lost oil. Some maintenance departments add a predictive element to gearbox maintenance in the form of oil sampling and analysis. Oil analysis, usually performed by an outside laboratory, reveals if the oil in a gearbox has lost its ability to lubricate and will detect any metal particles in the oil, a telltale sign of gear wear that foreshadows a possible failure.

These gearbox maintenance measures are time consuming and expensive and require shutting down the equipment. Also, gearboxes often are in inaccessible or unsafe locations that make oil-level checking and oil sampling difficult. For that reason, many predictive maintenance (PdM) programs also use thermography to detect when a gearbox is running hotter than similar gearboxes performing similar work in similar environments.



The gearbox on this conveyor belt motor assembly is abnormally warm. The clue is the white-hot shaft at the center.

What to check?

Use your thermal imager to scan the surface temperature of the gearboxes on every piece of critical equipment in your plant as determined by key operations, maintenance and safety personnel. That is, scan the gearboxes on all assets whose failure would threaten people, property or product. Know the load on each piece of equipment, and check each gearbox when it is running at a 40 % or more of its usual mechanical load. That way, measurements can be properly evaluated compared to normal operating conditions. If possible, for comparison, capture images of gearboxes in the same area performing the same or similar functions.

What to look for?

Because thermography is a non-contact, non-destructive technology, even inaccessible gearboxes in dangerous locations can be scanned while running. Capture thermal images as well as digital images of all critical gearboxes that are running hotter than normal. Look, too, for leaking seals. Thermal images can reveal hot oil running down gearbox cases.

Be aware that while all excessive heat generated in mechanical drive components is the result of friction, it may have sources other than inadequate lubrication. For example, its source might be friction caused by faulty bearings, misalignment, imbalance, misuse, or just normal wear. Thermography is a good first step toward a complete analysis of a critical mechanical drive's condition.

Using a thermal imager, you can also monitor the temperature of critical gearboxes over time and establish trends that will dictate when maintenance is required to prevent failure. A good approach is to create regular inspection routes that include the gearboxes on all key production assets. Save a thermal image of each one on the computer and track your measurements over time, using the software that comes with the thermal imager. That way, you'll have baseline images with which to compare later images. They will help you determine whether overheating is unusual or not and if corrective action is successful.

What represents a "red alert?"

Equipment conditions that pose a safety risk should get the highest priority for repairs.

However, the imminent failure of any piece of critical equipment constitutes a red alert. The same key operations, maintenance and safety personnel who determine which production assets are critical should play important roles in quantifying "warning" and "alarm" levels for those assets. (Note: alarm levels for specific equipment can be set on Fluke handheld thermal imagers.)

What's the potential cost of failure?

For a failed gearbox on a specific mechanical drive at your plant, you can do an analysis of the cost of the repair, lost production opportunity and lost labor costs.

At one automotive facility, for example, the estimated cost of the failure of one of the transfers that move vehicles through assembly stops the entire line. And even though most of these units are equipped with a backup drive, it once took maintenance personnel from 45 minutes to one hour to manually switch to the backup. At losses of US $3,500 per minute, a failed gearbox cost more than US $200,000 in lost production in addition to repair or replacement costs.

Follow-up actions

When you find an overheating gearbox, its thermal image may offer hints as to the cause of its abnormal operating temperature. For example, if an oil pump has failed, its inlet and outlet temperatures will be the same. But whatever the suspected cause of overheating, you can arrange to follow up by checking the oil level, oil quality and metal-particle content of the oil or perform acoustical testing or vibration analysis.

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report, including a thermal image and a digital image of the equipment. That's the best way to communicate problems you find and to suggest repairs.

An imaging tip:

Do you need to go into a dirty or wet environment with your Fluke handheld thermal imager? Cover it with a thin-film plastic bag, either clear or not. If you need to measure temperatures and not just compare relative temperature levels, you may want to first characterize the exact effect the bag has on readings by checking a reference with and without the bag in place.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

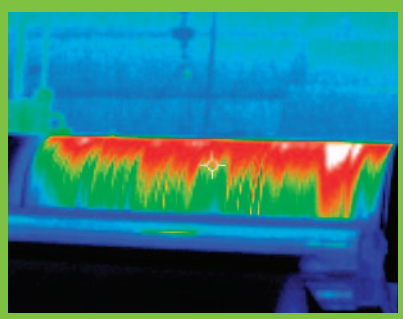
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 9/2005 2531331 A-EN-N Rev A

FLUKE®

Thermal process monitoring

Application Note

In process manufacturing, uniformity is essential. Technicians rely on monitoring of all kinds, from fixed mount sensors to handheld thermal imagers to track the condition of product and critical equipment. That's because temperature measurement and control is one of the single most significant variables for uniformity across process industries.



This thermal image highlights uneven cooling on a cooled paper roller.

Temperature monitoring can detect overheating delivery system components, help solve irregularities in electrical power supplies, predict operational machinery failure, detect blockages in supply pipes, and identify product inconsistencies.

Given the number of process industries and associated equipment variations, the possibilities for thermal monitoring are endless. One approach is to monitor critical assets the most often, followed by equipment in harsh environments. For example, the sludge, solvents and particulates found in many processes puts extra stress on motors, affecting bearings, windings and insulation. That stress shows up as heat detectable by a thermal imager.

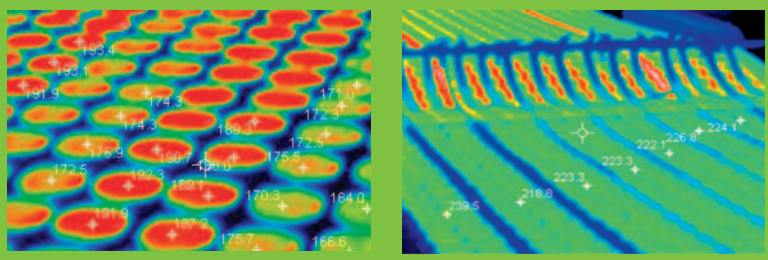
What to check?

Power distribution systems. Consistent, high quality power is essential for process manufacturing. Thermal imagery can identify bad electrical connections, imbalances, overloads, harmonics, and other impending electrical equipment failures and prevent both uneven or inadequate power supply as well as downtime.

Motors, fans, pumps, conveyors. Thermal inspections of the bearings, shafts, casings, belts, gearboxes and other components that emit heat before failure can prevent unexpected equipment breakdowns on moving equipment.

Heat processes. Paper, glass, steel and food product production all require the uniform application of heat. These processes often utilize thermocouples or infrared temperature sensors for thermal control. Frequently, spot measurements are not adequate due to process variations. Line scanners provide continuous thermal profiling in these cases, while portable thermal cameras can troubleshoot problems and determine the optimum spot to install the thermocouple or infrared sensor.

Pipes. In processes, fluids need to be delivered to the right place at the right time and in the right amounts. If a pipe is obstructed it can cause a chain reaction that throws an entire process loop out of tune, creating oscillation. This will cause motors to cycle on and off too frequently, which in turn causes more frequent current surges that stress the electrical system and



By canning product at different points in production as with these cookie and cracker production lines, thermal imaging can help spot check quality and troubleshoot irregularities.

add harmonics that lower system efficiency and ultimately lead to equipment failure. Thermography can often pinpoint an obstruction, allowing corrective action before the whole loop goes down, and the loop can be recalibrated by a multi-tasking tech using loop calibrators and digital multimeters.

Valves. Process control valves are also critical to delivering fluids to processes at the right time. A thermal imager can monitor for leakage, stiction (sticking) or excess friction. Also, a valve's excitation coil may overheat from working too hard, pointing to a problem such as current leakage or valve size mismatch. When thermography indicates a problem, technicians can follow up by calibrating the valve or the valve's positioner.

What to look for?

In specific processes, use your thermal imager to look at product uniformity. For example, if you have a paper process, you probably process the paper running it through an oven to cure it. The coatings applied often require a combination of time and temperature to achieve the right cure point and final moisture level. Use your handheld thermal imager to examine the thermal uniformity of the product as it comes out of the oven. Thermal variations are often attributable to other process variables such as non-uniformity in moisture or cure.

In general, use your handheld thermal imager to look for hotspots, cool spots and other anomalies. Here are some suggestions about critical equipment to monitor and what thermography might detect: motors (hot bearings and windings), motor control centers and switchgear (imbalance, overloads), steam systems (failed traps, obstructed piping), cooling systems (fouled cooling towers, blocked heat exchangers), furnaces and boilers (damaged refractory, leaking ports), pumps (hot bearings, leaking seals), process piping (ineffective insulation, reduced flow), tanks and vessels (product or sludge levels, leaks), valves (leakage, stiction) and conveyors (hot bearings and drives).

Each time you inspect a piece of equipment, save a thermal image of it on the computer and track its condition over time. That way, you'll have baseline data for comparisons that will help you to determine whether a hotspot (or cool spot) is unusual or increasing over time and also to verify when repairs are successful.

Follow-up actions

Whenever a thermal image detects a problem, use the associated software to document your findings in a report that includes a digital, photograph as well as a thermal image of the equipment. It's the best way to communicate the problems you found and to suggest repairs. In general, if a catastrophic failure appears imminent, the equipment must either be removed from service or, if possible, repaired while operating.

What represents a "red alert?"

Equipment conditions that pose a safety risk should take the highest repair priority. However, the imminent failure of any piece of critical equipment constitutes a red alert. The same key operations, maintenance and safety personnel who determine which production assets are critical should play important roles in quantifying "warning" and "alarm" levels for those assets. (Note: alarm levels for specific equipment can be set on Fluke handheld thermal imagers.)

What's the potential cost of failure?

Here are representative hourly downtime costs for some selected process industries: Energy, US $2.8 million; Pharmaceuticals, US $1 million; Food and Beverage, US $800,000; Chemicals, US $700,000; Metals, US $550,000. These figures are tied to loss of IT performance, but are cast in terms of general downtime.*

*Source: IT Performance Engineering and Measurement Strategies: Quantifying Performance and Loss, Meta Group, Oct. 2000; Fibre Channel Industry Association as found on the Web site of the Association of Contingency Planners, Washington State Chapter – www.acp-wa-state.org.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

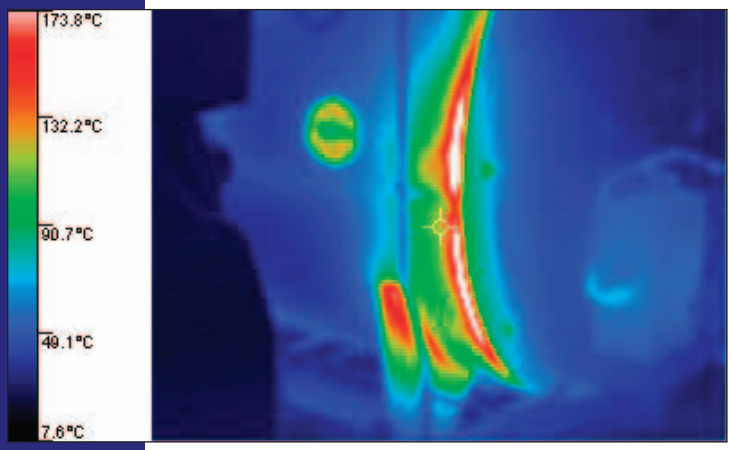
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2526394 A-EN-N Rev A

FLUKE®

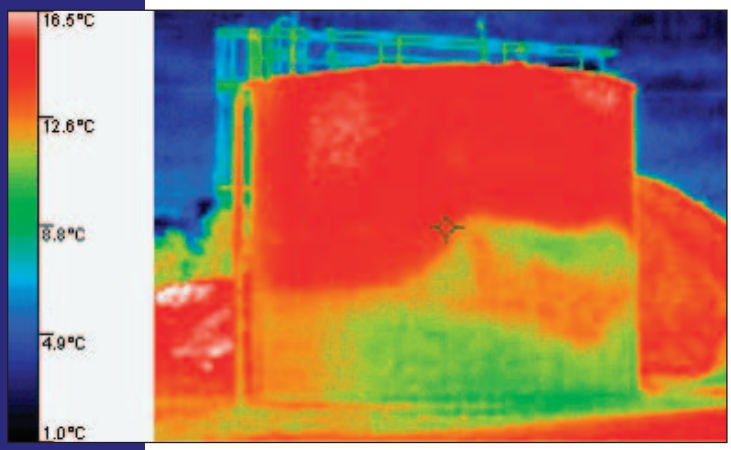
Example:
Tanks and vessels

Application Note

When technicians want to troubleshoot tank flow disturbances or determine the product level inside a vessel without opening it, there is one especially powerful tool to assist them: a Fluke thermal imager.



This tank may have leaks in the seams.



The temperature differentiation in this image probably indicates the transition between substances (a gas and a liquid) as well as some potentially uneven settling.

Above ground tanks and vessels for liquids and gases abound in chemical, food, pharmaceutical, and other process manufacturing. These vessels may be specially lined to store a variety of fluids from potable water to acids designed for mixing, blending, leaching, heating, cooling and oil-water separation processes.

By capturing two-dimensional temperature profiles of vessels, thermal imagers can detect temperature differences on the surface that often reveals conditions inside.

What to check?

Scan the outside surface of tanks for differences in temperature at different points. Also pay attention to gaskets, seals, and valves at openings.

What to look for?

While most large process tanks have built-in visual or electronic indicators for tracking product levels, they are not always reliable. Thermography can reveal the interface between the liquid and the gas (usually air) in a vessel, indicating how full it is and whether the contents have settled or separated inappropriately. Knowing the correct levels avoids overfilling when a level sensor is faulty and ensures reliable inventory figures for raw materials and/or finished products, allowing companies to balance processes and avoid product shortages or overruns.

FLUKE®

Tanks usually contain liquids or gases. The gases have a higher heat capacity than the liquids, meaning the liquid products change temperature much more slowly than the gas in the headspace. Since most tanks are located outside, their contents heat up during the day due to solar loading, and cool off at night. This temperature difference between the product and the headspace can usually be readily observed through most tank walls. This technique works best in the hours following sunset. Imaging the tanks in broad daylight is often difficult but favorable results are often achieved by examining the northern or shady side of the tanks during daylight hours. **Warning:** Make sure no one attempts to add to a vessel's contents until you have confirmed the level or available capacity.

A thermal image of a tank that is completely empty or completely full, or that has a shiny reflective skin, will appear uniform and no product level will be apparent. Otherwise, the product level will appear as an obvious thermal separation between the headspace and the product.

A properly captured thermal image will also reveal sludge buildup on tank bottoms, which can lead to premature corrosion and make it difficult to calculate the amount of product stored. Periodic monitoring will help you determine a cleaning schedule and track any changes in the rate of buildup. You will save money by cleaning tanks only when they need it.

Thermography can also reveal floating materials such as wax and foam as well as layers of different liquids, gases and even solids, such as the layer of paraffin that sometimes forms between the oil and water layers in separators, hindering their normal operation. Finding and correcting such situations will prevent loss of the separation process and subsequent loss of sales.

When performing tank and vessel inspections, be aware of factors that can introduce errors. Environmental conditions, the diverse thermal-conductive properties of different materials, natural or process-related convection within tanks and vessels, and even the curved surfaces of the vessels themselves can all affect thermal image accuracy.

Other tank and vessel conditions that can be monitored using thermography include damaged refractory or liners and leaks in tank walls. Under the right conditions, a damaged refractory or liner will show up as hot or cool spots. Most leaks occur because of the failure of a seal or gasket, although sometimes corrosion will lead to a leak in a vessel's wall. Whatever its origin, a leak is likely to manifest itself as a temperature anomaly.

What represents a "red alert?"

Equipment conditions that pose safety or environmental risks should receive the highest repair priority. Those would include conditions that might lead to potential leaks or overflows of vessels containing hazardous materials. Any malfunction that could disrupt production must also be avoided.

What's the potential cost of failure?

The cost of a failed tank to a company depends on many factors including whether a hazardous spill is involved. An uncontained leak in a large oil tank, for example, might cost a company US $700,000 or more—at least US $500,000 for an environmental cleanup and US $200,000 for a replacement tank.

Regarding downtime caused by tank or vessel problems, here are some representative hourly downtime costs for selected industries that use tanks and vessels extensively: Pharmaceuticals, US $1 million; Food and Beverage, US $800,000; Chemicals, US $700,000. These figures are tied to loss of IT performance, but are cast in terms of general downtime.*

Follow-up actions

Use the reporting software that comes with the imager to document findings, and include both a digital image of the equipment as well as a thermal image. It's the best way to communicate the problems you found and any suggestions for correcting them. Following corrective action, take a new thermal image to assess the repair's effectiveness.

*Source: IT Performance Engineering and Measurement Strategies: Quantifying Performance and Loss, Meta Group, Oct. 2000; Fibre Channel Industry Association as found on the Web site of the Association of Contingency Planners, Washington State Chapter—www.acp-wa-state.org.

An imaging tip

Trying to find a level in a tank or vessel that is covered with an aluminum cladding or some other low-emissivity coating is almost impossible. To overcome such a handicap, put a vertical strip of paint or tape down the side of the vessel. If the unit is outside, put the high-emissivity stripe on the shady side.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2526382 A-EN-N Rev A

FLUKE®

Inspecting furnaces and boilers

Application Note

Furnaces and boilers play important roles in many industries as well as in the heating of commercial and institutional buildings. They heat products in petroleum, chemical and pharmaceutical industries and produce or handle molten products in glass, steel and other industries. In most cases, if only because of their high operating temperatures and their capacity to cause injury or death as a result of some failures, furnaces and boilers should be included in predictive maintenance (PdM) programs that monitor their condition while they operate.

Check for abnormal hot spots indicating refractory insulation breakdown.

The purpose of a PdM program is to detect and prevent imminent failures before they occur to avoid the shutdown of critical equipment. One especially powerful tool for monitoring the condition of furnaces and boilers is thermal imaging, which captures two-dimensional images of the temperature profiles of objects. Thermal images can reveal potential points of failure in furnaces and boilers and help extend the life of their refractory insulation.

The following discussion focuses on using thermal imaging or thermography to troubleshoot furnaces and boilers, especially the refractory insulation directly inside a unit's exterior wall or the insulating lining of vessels handling or conveying molten material.

What to check?

Use a thermal imager to check any critical furnace, process heater or boiler, prioritizing those whose failure could threaten human health or safety, property, productivity or the product itself.

Highly skilled thermographers report some success checking the tubes of furnaces and boilers for hot spots, which can signal a potential failure. Clearly, a breach in the wall of a tube containing very hot water, steam or hot product could be catastrophic, but those who would attempt to use thermography for such monitoring must realize that to do so is difficult and dangerous, putting both the thermographer and the imaging instrument at risk. Also, it requires substantial knowledge, training and experience to get reliable results in environments as harsh as the inside of a furnace or boiler.

By contrast, as long as a unit does not have a shiny surface, exterior thermographic inspections of furnaces and boilers are relatively safe and easy and can help determine the unit's health.

What to look for?

To protect personnel and property, furnaces, boilers, process heaters and other heat-generating units have insulation or refractory lining their external

walls. Using a thermal imager, technicians can look for hot spots on the walls. The hot spots will reveal where the refractory is less effective. The goal is to maximize the useful life of the refractory and to schedule repairs before a burn-through of the unit's wall results in fire, injury or worse. Of course, a secondary concern with ineffective insulation or refractory is energy loss, which increases operating costs and can jeopardize process efficiency due to heat loss.

A sound approach to furnace and boiler inspections is to create regular inspection routes that include all key furnaces, boilers, process heaters and other heat-generating equipment. A good approach is to determine the frequency of inspections based on the nature and function of the equipment. For example, you might perform quarterly inspections on indispensable equipment operating under severe conditions and annual inspections on equipment operating under less severe conditions.

What represents a "red alert?"

Equipment conditions that pose a safety risk should always receive the highest repair priority. Clearly, one of the most potentially dangerous situations that might occur is the failure of a furnace or ladle for a molten material such as glass or steel.

Monitoring such equipment serves a two-fold purpose: 1) to maximize the life of the unit's refractory and 2) to guard against a breakout that discharges very hot molten materials into a facility.

What's the potential cost of failure?

A catastrophic failure in the glass or steel industry would constitute a multi-million dollar production stoppage, even if there were no injuries or deaths. Cold glass cannot be reheated. And how does one recover solidified, once-molten iron or steel?

Here are some representative hourly downtime costs for some selected industries in which boilers, furnaces and process heaters are key to production: Pharmaceuticals, $1 million; Food and Beverage, $800,000; Chemicals, $700,000; Metals, $550,000. These figures are tied to loss of IT performance, but are cast in terms of general downtime.*

Follow-up actions

When you discover a problem using a thermal imager, use the associated software to document your findings in a report that includes a thermal image and a digital, image of the equipment. It's the best way to communicate the problems you found and any suggested repairs.

In general, if a catastrophic failure appears imminent, the equipment must either be removed from service or repaired while operating. In the steel industry, both strategies are employed. When it comes to ladles for molten product, mills generally have enough ladles to take a failing one out of service for repairs and replace it with a sound one. However, the refractory in some kinds of furnaces and heaters in the steel industry can be repaired during operations using a grout pumped onto areas of weak or damaged refractory (as identified in a thermal image).

In either case, following repairs, new thermal images can be used to assess the effectiveness of repairs and evaluate the repair materials used. With this information, you can continuously improve your PdM program for furnace and boiler refractories.

*Source: IT Performance Engineering and Measurement Strategies: Quantifying Performance and Loss, Meta Group, Oct. 2000; Fibre Channel Industry Association as found on the Web site of the Association of Contingency Planners, Washington State Chapter - www.acp-wa-state.org.

Imaging Tip:

A comprehensive comparative or qualitative analysis of refractory can yield substantial cost benefit. A detailed infrared examination of a new ladle or relined refractory wall, contrasted with a similar infrared examination of a similar ladle or furnace wall just prior to relining, can help you establish benchmarks for performance. These benchmarks become the future standards for determining acceptance criteria for a new unit, and guide the user for determining when the next relining is required.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800) 36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 8/2005 2524871 A-EN-N Rev A

FLUKE®

Teamwork, tools and techniques:

How one plant brought thermography in house

Application Note

Testing Functions **Case Study**

By using thermal imaging, Alltech determined that insufficient airflow and cooling was causing this pump seal to fail, saving a $100,000 project from ongoing seal failure.

Measuring tools: Fluke Ti30 Thermal Imager

Operator: Barry Ungles, Alltech Electrical Service and Len Sisk, maintenance team leader at BP Jayhawk Gas Plant

Inspections: Electrical, valves, pipes, vessels, compressors, motors, switchgear

This story is about a BP natural gas operation in Ulysses, Kansas. The Jayhawk plant processes gas from the wells of several different companies, including its own. To get the gas from its wells to the plant, BP uses compressor stations that boost the pipeline pressure of the natural gas after it flows out of the ground. At the plant, several processes strip waste products off the gas, verify the refined natural gas meets proper BTU contents for distribution, and produce helium, nitrogen, and propane by-products. Then, the company delivers the refined natural gas to a pipeline headed east.

One of the plant's contractors, Alltech Instrumentation & Electrical Service, has long performed onsite electrical installation and service work for the main facility and its gas fields. Their daily work ranges from replacing electric motors and running conduit to automation controls, to wiring for AFR (air/fuel ratio) controllers for the compressors and helping field and plant technicians with repairs.

Then, Alltech added thermal imaging to their electrical services. Up until that point, electrical and thermography had been handled as two separate services, but as it turned out, Alltech's knowledge of the plant's equipment, their daily presence and their ability to make electrical repairs created a far more efficient all-in-one service.

Now, according to Len Sisk, Maintenance Team Leader at the BP plant, "We're realizing significant cost savings just by doing more thermal imaging."

The tool

Thermal imaging is ideal for measuring electrical equipment, and this plant has plenty of it—about 115,000 kilowatts coming in. Until recently, the facility had been using a secondary contractor from six and a half hours away to conduct annual thermal imaging surveys of its key electrical equipment.

This arrangement was problematic. When plant personnel needed a problem assessed, six and a half hours was too long to wait for a thermographer, especially in downtime situations. Then, new thermal imagers came on the market that were more affordable than the traditional models but still powerful enough for facility maintenance and significantly easier to use. So, Alltech purchased a Fluke Ti30 Thermal Imager, sent their operations manager, Barry Ungles, to training, and began inspecting plant equipment.

At first, says Sisk, the facility didn't realize the full potential of having an in-house imager. But, within months, Alltech had moved from just on-demand inspections to inspecting switchgear, junction boxes and other high voltage systems, conducting regular inspections of field equipment, and taking over the annual thermal inspection contract. Sisk has already found uses for the imager in vessel, pipe and valve inspections, and plans to use thermography to inspect low-temperature cryogenic processes, as well.

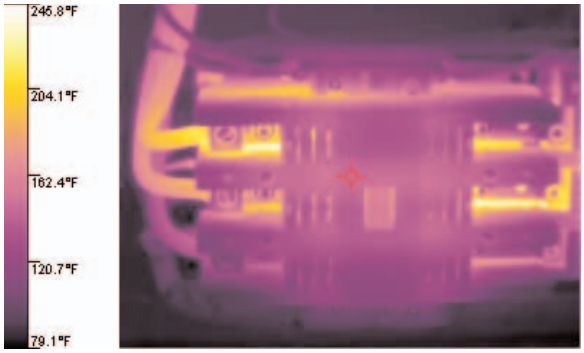
The in-house move made sense. The thermography-only contractors hadn't been authorized to remove panel doors or make other electrical adjustments necessary to get clear thermal images. That meant the facility's electricians had to be involved. As licensed electricians, Alltech now does all of that. They're also able to interpret the electrical significance of the thermal images, and in some cases, proceed immediately to repairs and then verify their success with additional thermal images.

Technique

Every year, Alltech spends about three days scanning the plant for electrical problems. The two power control rooms are divided into sections, or buckets, that contain switchgear and breaker sources for the power supply and distribution. The electricians monitor everything in the buckets, checking all of the operating stations and making thermal images of all the electrical connections—from relays to transformers. Among other things, they use the imager to look for loose connections, because that's where major problems such as meltdowns often occur.

"Because the Ti30 Thermal Imager can measure components to one-quarter of a degree," says Ungles, "we can find wire lugs that are loose but overheating only slightly. That means that we can detect potential problems long before they become serious problems. In some cases, we can tighten lugs on the spot if it's safe to do that." For more serious problems and for equipment carrying very high voltage, Ungles takes a thermal image and a digital photo of the unit and sends a report to the supervising plant technician.

Electrical components are not the only thing Ungles monitors at the plant. One example is the sludge catcher, the big vessel that collects waste from the natural gas. "At one point," says Ungles, "plant personnel weren't sure their level indicators were working correctly, which meant they weren't sure how much sludge was in the vessel. I made thermal images of this unit at the end of a hot day when the vessel had begun to cool. The image revealed the line between the heated sludge and the unrefined natural gas above it in the vessel, which cooled faster. Thermography proved to be a failsafe backup to the level indicators." A vessel entry to determine the sludge depth would have required a major plant shutdown and an extremely dangerous vessel entry. "With thermal imaging," says Len Fisk, "we were able to determine this depth for a fraction of the cost of conventional methods."



Example of a hot connection on panels in the BP Jayhawk Plant power control rooms. Abnormal connection heat can be caused by overly loose or tight connections, corrosion, overloading, unbalance, harmonics and other electrical problems.

Thermal images of this sludge catcher vessel revealed the line between unrefined natural gas and heated sludge, saving the plant from a major shutdown required for manual verification.

In another case, says Sisk, the plant wanted to determine which valve in a faulty system needed to be replaced. Conventional troubleshooting methods were ineffective due to plant operating constraints and replacing all of the valves would have cost $15,000. So, the plant used the thermal imager to locate temperature deviations in the system, identified the faulty unit, an replaced just one valve.

The imager also saved a $100,000 project at risk due to faulty pump seals, when the vendor engineers could not solve the problem. Thermal imaging revealed that the seal failure stemmed from overheating caused by insufficient flow and cooling—not from a faulty unit. If the pump seal had simply been replaced and the real problem left uncorrected, the failure would have lead to a spill.

In the gas fields, the Alltech electricians use the Ti30 Imager to monitor mechanical devices. Thermal images can detect alignment problems in rotating equipment—for example, between a motor and a compressor. With a thermal image, they can quickly discover when a bearing is heating up because of misalignment.

They also use thermography to monitor 24-volt control circuits. On these low-voltage installations, the imager permits them to pinpoint loose connections as potential future problems, tighten them and prevent failures at a later date. Using the Ti30 Imager, Alltech has found loose 24-volt connections that, because of the rating of the wire, weren't yet problems. Still, if those connections had kept vibrating until the screws came out, the wires might have come out of their sockets and caused shutdowns.

Teamwork

With basic training on thermal imaging and good communication on the plant floor, many different facility teams can benefit from thermal imaging. For example, the plant uses extremely cold processes to remove the unwanted gases from the natural gas. In one case, a nitrogen pump had a persistently leaky seal. It had to be changed out regularly.

The electricians took a thermal image of the pump. An engineer took one look at the image and realized immediately that there a restriction preventing the seal from receiving enough cooling airflow. As a result, the seal was overheating and melting.

The software included with the imager helps the user set up inspection routes for the regularly scheduled inspections at the plant and in the field,

and to adjust measurement parameters such as emissivity, RTC, temperature level and gain for particular locations and pieces of equipment.

Ungles use the same software to report his inspection results. "It uploads all of the images I've taken and allows me to add side-by-side digital photographs, so that the technicians can translate the hot spots on thermal images to locations on the digital photos. I add notes and analysis to each image and rate the inspected equipment, designating which should get attention first. For example, if a wire is rated for a maximum temperature of 150 °F and my scan shows that wire fastened into a terminal lug that is more than 200 °F, then I know I am looking at a meltdown fairly soon. "

In general, says Ungles "I use "high," "medium" and "low" designations for scanned equipment with problems. "Low" means it can be addressed sometime. "Medium" means it needs to be to taken care of relatively quickly. "High" signifies do something right away. Each year, I put together a book of my findings, and the facility keeps that book on hand to guide its PdM activities." In additional to thermal imaging, the BP plant in Ulysses also uses oil sampling analysis and vibration analysis on its compressors, VOC packing leak detection on valves and pumps, hi-pot insulation resistance testing, and regular switchgear cleaning and electrical maintenance.

The only warning here is to watch out for snowballs. As this plant found out, once thermal imaging comes in house, applications for it appear everywhere, operation costs start to drop, and efficiency improves. What's a plant manger to do?

Thermography and PdM

Thermal imagers capture images created by the otherwise invisible infrared (IR) radiation emitted from objects. These images show a range of temperatures represented as color or tone variations and allow observers to pick out hot spots (or cold spots) that might signal electrical or mechanical, or process flow problems.

Predictive maintenance (PdM) is a maintenance method that advocates regularly collecting measurements and tracking key indicators over time to predict when key equipment needs to be repaired to avoid failure. Petrochemical and energy companies as well as discrete manufacturing companies invest much capital in production and processing equipment. Delivery schedules and profits can be adversely affected by machine downtime. So, identifying impending equipment failures and preventing them before they happen can result in lower maintenance costs and fewer production losses.

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

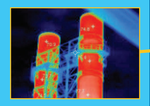
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 9/2005 2519644 A-EN-N Rev A

Thermal Imaging Applications

FLUKE

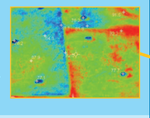
Buildings

Chimney



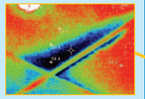
- What to look for: Industrial chimneys accumulate materials on the inside lining that can appear as a cool region, if the material causes an insulating effect, or as a hot spot. Hot spots can also indicate cracks/gas leaks and developing failures in the refractory insulation.
- What this image shows: Minor cool anomalies, indicating possible buildup.
- Recommendations: Monitor over time, consider investigating with secondary method
- Cost of failure: Chimney fire, leaking hot gas, structural failure.

Roof



- What to look for: Anomalies indicating moisture. Check outside walls and roof after a hot day. Ensure roof is properly sealed.
- What the image shows: Clear moisture differentiation at rubber roof seams.
- Recommendations: Use a moisture meter and/or a core sample to verify the thermal indication.
- Cost of failure: US$4 to US$8 /sqft to replace roof; damaged contents; energy waste from heating/cooling loss.

Moisture and insulation leakage



- What to look for: Check ceilings and walls for cool and hot thermal anomalies. Moisture can be hot, if conducting, and cool, if evaporating. Air leakage can be into (cool) or out of (hot) a building.
- What the image shows: Moisture in a drop ceiling.
- Recommendations: Follow up with core samples and a moisture meter. Check for for leaks, water pipe breaks, fire-sprinkler discharges, uneven insulation, and damaged seals.
- Cost of failure: Damage to building structure = material+labor; heating/cooling loss = energy waste; mold = health risk.

Electrical

Deteriorated Connections

- What to look for: Compare temperatures of connections and switch contacts, look for abnormally hot or cool connections.
- What the image shows: Abnormal heating at the point of the connection or switch contact. (Abnormally cool would mean complete device failure).
- Recommendations: A ΔT between similar components under similar loading exceeding 15°C (27°F) requires immediate repair. Use a DMM, clampmeter or power quality analyzer to investigate. Look for corroded or loose connections.
- Cost of failure: Electrical distribution failure/downtime; electrical fire.

Three-phase Unbalance and Overloads

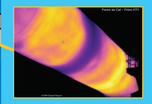
- What to look for: Compare temperatures between phases on high-load connections; An abnormally hot phase can indicate unbalance or overload.
- What the image shows: Abnormal heating along the entire circuit or phase run (not just at the connection). An imbalance heats both the line and load sides of the phase.
- Recommendations: Use a DMM, clamp meter or power quality analyzer to measure load. Look for a power delivery problem, low voltage on one leg, bad connections, insulation resistance breakdown, or harmonics.
- Cost of failure: Reduced load-equipment efficient, lifespan, and/or replacement, electrical distribution failure/downtime; electrical fire; higher utility rates.

Substations

- What to look for: Examine transformers and compare similar connections under similar loads, looking for hot or cool anomalies. Heat can be caused by harmonics, connection degradation, unbalance, or overload.
- What this image shows: Hot secondary connections on transformer.
- Recommendations: Conduct an electrical inspection to determine cause.
- Cost of failure: A melted connection can cause the switchgear to fault and shut down power to the facility, or cause an arc flash, causing major property damage and loss of production.

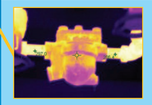
Process

Pipes



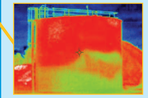
- What to look for: Check all transmission lines, including underground, for temperature anomalies indicating leaks and condensation in the bottom of the pipes.
- What the image shows: Yellow areas indicate abnormal hot spots, possibly related to a breakdown of the insulation. The cold blue band is probably a buildup of product on the inside.
- Recommendations: Further inspection and repair.
- Cost of failure: Total loss of steam to production costs US$1,100,000 an hour.

Valves and traps



- What to look for: While system is operating, compare inlet/outlet temperatures and check for condensation at the bottom of the trap. If inlet/outlet are same, trap has failed open; equally low inlet/outlet temp means trap failed closed.
- What the image shows: Trap failed open, plus condensation.
- Recommendations: Follow up with visual inspection and ultrasound check. Look for closed valves or pipe blockage.
- Cost of failure: Average yearly cost in steam-process plant of failed traps: US$27,000 to US$54,000.

Tanks and vessels



- What to look for: Check liquid and gas levels within tanks, look for settling or differentiation between air and solid material, and check for blocking at tubes.
- What the image shows: Liquid level and settling.
- Recommendations: Depends on tank contents and cleaning schedule.
- Cost of failure: Hourly tank downtime cost = US$800,000.

Motors

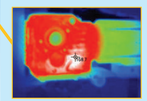
Bearing and shaft

- What to look for: Compare bearing and housing temperature against baseline images or other known acceptable thermal values. Compare end bell to end bell or stator to end bell temperatures.
- What the image shows: Warm bearing with heat transferring to coupling.
- Recommendations: Conduct a vibration analysis, measure lubrication, check windings, check electrical load balance.
- Cost of failure: Total motor replacement cost (US$7,000) + downtime (10 hours at US$1,000 per hour = US$10,000) = US$17,000.

Casing

- What to look for: Use the exterior thermal gradient as an indicator of the internal temperature. Other components should not be as hot as the motor housing. Each 10°C rise above its rated temperature cuts a motor's life in half.
- What the image shows: An abnormal thermal pattern, probably due to airflow/obstructed cooling or misalignment.
- Recommendations: Check nameplate for normal operating temperature. Use other test tools to check for inadequate airflow, impending bearing failure, shaft coupling problems, and insulation degradation in the rotor or stator.
- Cost of failure: Total motor replacement cost plus downtime

Gearbox



- What to look for: A properly functioning gearbox runs temperatures slightly above ambient, about the same as the motor housing case. Low lubricant or gear problems often show as hot spots.
- What the image shows: Motor (right) is uniformly cool, while gearbox (left) has a 158°F hot (white) anomaly at bottom right.
- Recommendations: Investigate mechanics (lubrication, gears) immediately.
- Cost of failure: Unit failure, replacement cost, lost production (see above)

Inspection Guidelines

Thermal Safety Guidelines

To keep your thermography inspections safe, accurate, and effective, establish written inspection procedures for measurement collection and interpretation.

- Personnel working in the proximity of energized electrical equipment must use proper personal protective equipment (PPE) and identify all energized components before beginning work.
- In the United States, refer to NFPA-70E (considered a relevant and reasonable standard by OSHA) for guidance on safety precautions and PPE.
- Outside of the United States, consult the relevant international, federal and local government requirements for electrical safety.
- For more information on electrical safety and standards, visit www.fluke.com/safety and request a free copy of the Fluke Electrical Measurement Safety video.

Equipment type	Frequency of inspection
High voltage substations	1–3 years
Transformers	annually
440 V Motor Control Centers	
Air conditioned	6–12 months
Non-air conditioned or older	4–6 months
Electrical distribution equipment	4–6 months
Large motors*	annually
Smaller motors	4–6 months

** Assumes vibration, motor circuit and lubrication analysis also being used.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206
©2005 Fluke Corporation. All rights reserved.
Printed in U.S.A. 7/2005 2507950 G-ENG-N Rev A
http://www.fluke.com/thermography
http://www.ti20.com